Sufficiency of existing measures for commercial fish in the Baltic Sea

ACTION

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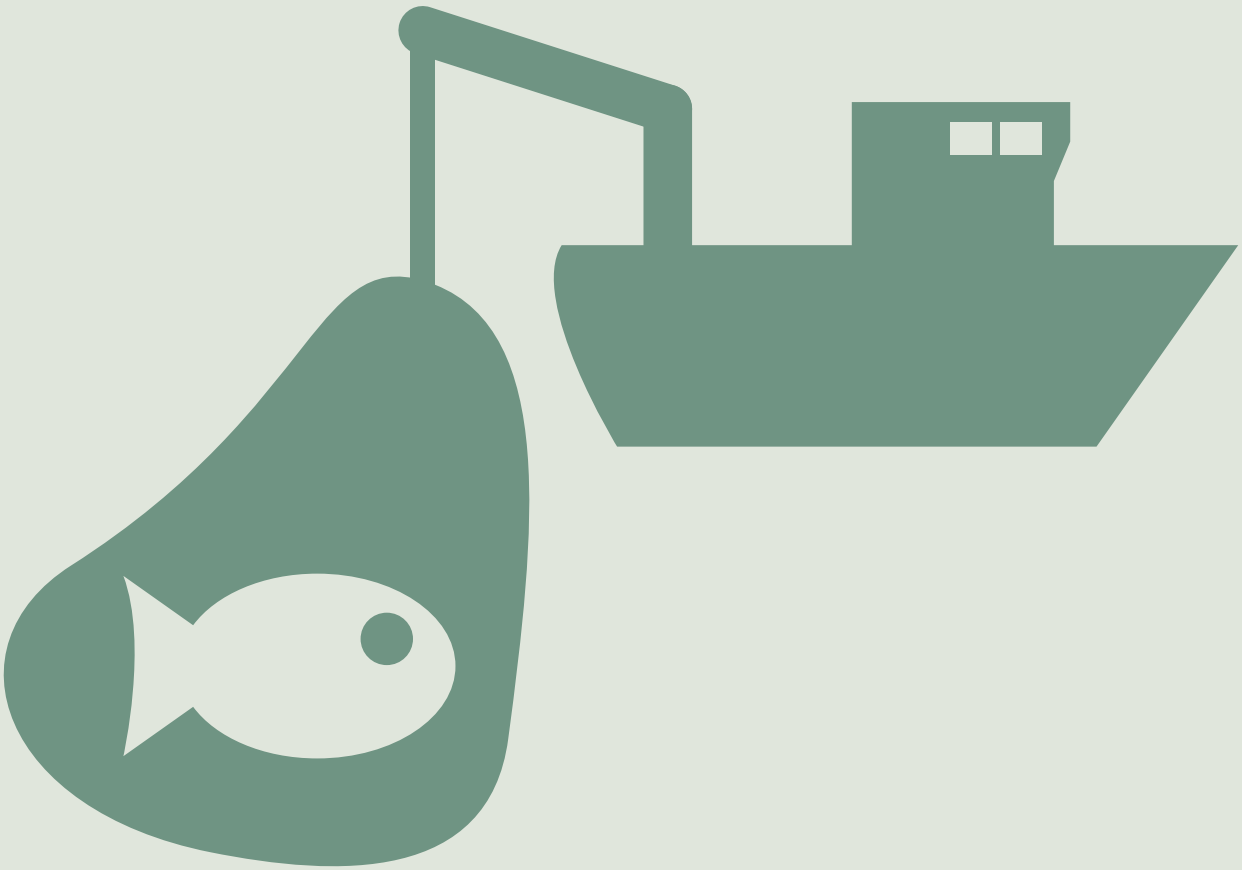
Species and biotopes

2021



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Summary of main results

SOM analysis for commercial fish has evaluated the probability to achieve GES or specific state improvements for herring, cod, sprat and plaice by comparing projected pressure reductions from existing measures to required pressure reductions.

The results suggest that existing measures could be sufficient in maintaining GES for herring in SD 25-29 and 32. Measures do not appear sufficient to achieve GES for herring in SD 20-24. For herring in SD 30-31, existing measures would likely be sufficient to achieve a 10% state improvement. For sprat, the probability to maintain GES with existing measures is moderate. For cod and plaice, results on sufficiency of measures to achieve GES are missing due to lack of data. The results are based on existing information about the stocks at the time of the study and may no longer reflect current conditions.

The main pressure affecting commercial fish is the extraction of fish (includes prey depletion). Other significant pressures are human-induced food web imbalance, change in hydrologic conditions and effects of eutrophication.

Seasonal and spatial closures, as well as technical measures to reduce catches of unwanted species or sizes of fish appear among the most effective measure types to reduce targeted extraction and bycatch of commercial fish from fish and shellfish harvesting. The estimates on the effectiveness of measure types are rather uncertain.

Contribution of activities to pressures was not assessed, as all pressures are created by a single activity or are not dependent on activities.

The overall certainty of the assessment for commercial fish could be characterized as low. Experts from six coastal countries contributed to the assessment. The total number of experts contributing to the surveys is high for both the effectiveness of measures and pressure-state part, but some individual elements suffer from a low amount of data. As the effects of some important pressures to the state of commercial fish have not been quantified in the analysis, the pressure reductions and probability to achieve GES/state improvements are likely underestimated. Additionally, there are concerns about the handling of dynamic management and the use of ICES reference values in the analysis.

It should also be noted that the results do not capture all aspects of relevance to the management of these fish populations, such as information on fishing mortality, population size structure and condition factors.

Introduction

Report background

The sufficiency of measures (SOM) analysis assesses improvements in environmental state and reduction of pressures that can be achieved with existing measures in the Baltic Sea region, and whether these are sufficient to achieve good environmental status (GES). The analysis involves estimating the state of the marine environment in 2030, based on a starting point of 2016 (i.e., the latest HELCOM status assessment), and given measures in existing policies, their implementation status, and the projected development of human activities over time. The evaluation can be carried out compared to relevant and agreed HELCOM threshold values for GES, where available.

The main aim of the SOM analysis is to support the update of the HELCOM Baltic Sea Action Plan (BSAP) by identifying potential gaps in achieving environmental objectives with existing measures for the Baltic Sea. In addition, the analysis can indicate both thematically and spatially where new measures are likely needed.

The same overall approach has been applied across all topics included in the SOM analysis to ensure comparability and coherence of the results, while considering topic-specific aspects and making necessary adjustments. The main components of the analysis include assessing the contribution of activities to pressures, the effect of existing measures on pressures, the effect of development of human activities on pressures, and the effect of changes in pressure on environmental state. The SOM approach, model and data collection are described in detail in the methodology report.

The methodology for the SOM analysis is designed to accommodate the broad array of topics relevant in the HELCOM region and to enable a region-level analysis. It balances between state-of-the-art knowledge, availability of data, and advice taken onboard from various HELCOM meetings and bodies.

The data used in the SOM analysis have been collected using expert elicitation and by reviewing existing literature, model outputs and other data sources. Data availability varies substantially across topics and data components, which is reflected in the presentation of the methods and results in this report.

The SOM analysis presents the first attempt to quantify the effects of existing measures and policies on the environment and achieving policy objectives for various environmental topics in HELCOM and the Baltic Sea area. It is aimed at assessing the overall sufficiency of existing measures at the Baltic Sea level. The results are based mainly on expert elicitation, and thus they should be utilized appropriately. Due to the pioneering nature of the approach and variable data quality and availability in the SOM analysis, the findings do not provide conclusive answers on the need for new measures, but indicate likely gaps, and should thus also be reviewed in relation to the results of other assessments.

This topic report describes the analyses carried out and the results for the SOM analysis on commercial fish, providing detailed topic-specific information. First, it presents background information and describes the data and methods for addressing the topic in the SOM assessment, including relevant assumptions and challenges. Second, it presents and

discusses the findings for each result component. Third, it provides discussion on the impacts of alternative assumptions and data, evaluates the quality and confidence of the analysis, and provides implications and future perspectives. The annexes contain detailed information on the data components, topic structure and expert surveys for the analysis, as well as supplementary results.

Similar topic reports have been prepared for all nine topics covered in the SOM analysis. In addition, the results are summarized in the main report and the full methodology is described in the methodology report.

Topic background

Description of commercial fish in the SOM assessment

Commercial fish are included in the SOM analysis as four state components: *Abundance of cod, Abundance of herring, Abundance of sprat,* and *Abundance of plaice* (Figure 1). These components reflect the structure of the MSFD criterion D3C2[1].

Each species is evaluated at the population level using the spawning stock biomass (SSB) assessments made by ICES and 2018 as the base year (Figures 2-5) (ICES 2019a-j). However, due to a variation between the management areas and population areas for plaice, a one-out-all-out approach has been adopted for this species using the plaice population with the poorest SSB status as the baseline condition for both populations (ICES 2019h-i). Additionally, in the course of the development of this topic in the SOM analysis, ICES downgraded the assessment category for herring in sub-divisions 30 and 31 (Gulf of Bothnia) from quantitative to qualitative. This stock was still included in the SOM analysis but is evaluated based on improvement from current conditions rather than based on a threshold value. All other state components are assessed against the quantitative spawning stock biomass threshold in use by ICES in 2019 (ICES 2019a-j). Table 1 presents the structure and base states of the SOM commercial fish assessment.

[1] Marine Strategy Framework Directive D3C2 – Primary: The Spawning Stock Biomass of populations of commercially-exploited species are above biomass levels capable of producing maximum sustainable yield. Appropriate scientific bodies shall be consulted in accordance with Article 26 of Regulation (EU) No 1380/2013.

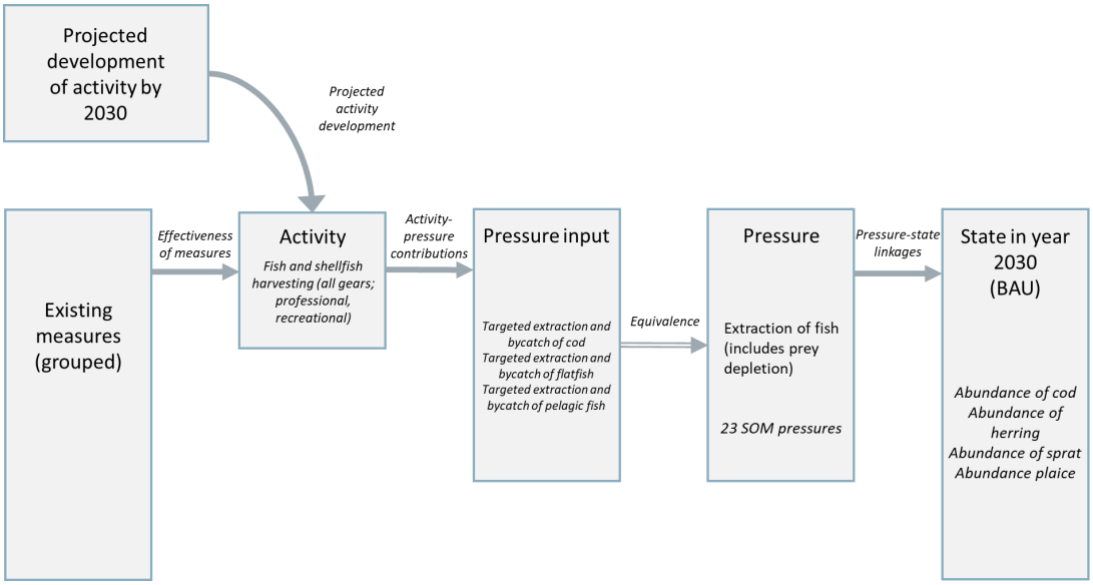

Figure 1. Schematic of the SOM model for commercial fish. While commercial fish can be influenced by any pressure in the model, they are only present in the model as a state component and therefore do not influence any other model component.

Table 1. Structure and base states of the SOM commercial fish assessments. The table presents each commercial fish assessment and the type of assessment made. For threshold-based assessments, the base state and threshold value are presented. Improvement-based assessments do not have a base state and show not applicable (NA) in the relevant columns. Base states are transformed values based on the ratio of the 2018 assessed stock spawning biomass to the corresponding MSY Btrigger value used in the ICES stock assessments (Bpa used for eastern Baltic cod; MSY Btrigger proxy used for plaice 24-32; see Annex 7).

Species	Assessment area	Assessment type	Base state	Threshold value
Cod	Eastern Baltic	threshold	0.78	1
Cod	Western Baltic	threshold	0.66	1
Herring	SD 20-24, spring spawners	threshold	0.49	1
Herring	SD 25–29 and 32, excluding the Gulf of Riga	threshold	1.56	1
Herring	SD 28.1 (Gulf of Riga)	threshold	1.84	1
Herring	SD 30-31	% improvement	NA	NA
Sprat	SD 22-30 and 32	threshold	1.97	1
Plaice	Occurrence of plaice	threshold	2.11*	1

*Based on one-out-all-out principle, this status is based on plaice in SD 21-23.

Fish specific pressures

For the fish specific pressures, pressure input and pressure are equivalent and only the term pressure is used further in the report (see Figure 1). Several assessed pressures are exclusive to fish, including *targeted extraction and bycatch of fish* for coastal fish, cod, flatfish, pelagic fish, salmon, sea trout and eel, as well as *disturbance of species: obstructions (dams)* The targeted extraction pressures do not correspond to a HELCOM indicator but are assessed by ICES for many commercial species (ICES 2019a-j). Additionally, MSFD criterion D3C1[2] and to a limited extent D1C1[3] apply in combination to these pressures. The pressure *disturbance of species: obstructions (dams)* does not correspond to a HELCOM indicator but is a quality element of ecological status for rivers under the Water Framework Directive (River continuity). These pressures all originate from either a single activity (*targeted extraction and bycatch* is only caused by fishing) or are not connected to a SOM activity (*disturbance of species: obstructions (dams))*. None of these pressures are assessed against a GES threshold in the SOM analysis.

[2] Marine Strategy Framework Directive D3C1 – Primary: The Fishing mortality rate of populations of commercially-exploited species is at or below levels which can produce the maximum sustainable yield (MSY). Appropriate scientific bodies shall be consulted in accordance with Article 26 of Regulation (EU) No 1380/2013.
[3] Marine Strategy Framework Directive D1C1 – The mortality rate per species from incidental by-catch is below levels which threaten the species, such that its longterm viability is ensured.

Methods and data

The section below includes an overview of any topic-specific methodologies. A full description of the general approach, methods and data collection for the SOM analysis is available in this document. Note that the detailed results are presented for the most likely development of human activities and using the expert data on effectiveness of measures.

Effectiveness of measures and pressure-state linkages

Measure types (Annex 3) and structural relationships between the measure types and activities and pressures (Annex 7) were designed by the HELCOM Workshop on the analyses of Sufficiency of Measures (SOM) for Fish (SOM-FISH WS 1-2019) in collaboration with HELCOM ACTION WP6. The measure types were informed by the existing measures list (Annex 4) but were also designed to acknowledge the full breadth of potential measures.

For commercial fish, the effectiveness of measures survey structure comprised 12 unique measure types covering one activity. The same measure type may be listed under multiple pressures. Altogether this resulted in 35 assessments of measure type effectiveness across the three pressures, *targeted extraction and bycatch of cod*, *targeted extraction and bycatch of flatfish*, and *targeted extraction and bycatch of pelagic fish*. The exact list of measure types, and their grouping by activities and pressures is shown in Annex 7. The effectiveness of measures survey itself is included as Annex 8.

Effectiveness of the measure types and links between the pressures and state components were determined using online expert surveys implemented in December 2019 – February 2020 with follow-up surveys conducted in the spring 2020. The expert pool consisted of the HELCOM Group on Ecosystem-based Sustainable Fisheries, HELCOM Task Force on Migratory Fish Species, HELCOM Project for Baltic-wide assessment of coastal fish communities in support of an ecosystem-based management, participants of the HELCOM Workshop on the analysis of sufficiency of measures for fish and nationally nominated experts. Additionally, the project received survey responses from experts not on the original invitation list; these responses were also included in the analysis. The full description of the methodology and data collection is available as part of the SOM methodology report.

Pressure reductions and state improvements

The projected reductions in pressures are calculated using the data on effectiveness of measure types, links between existing measures and measure types, and projected development of human activities. They account for the joint impacts across the measure types, as well as the spatial area where the pressures can be reduced to avoid overestimating the pressure reductions. Pressure reductions can be positive (pressure is reduced), negative (pressure is increased) or zero (no change in pressure), depending on the combined effect of existing measures and changes in the extent of human activities. When the reduction in pressures from existing measures is larger than the increase from changes in human activities, pressures are reduced.

The calculation of sufficiency of measures takes into account all the components of the SOM analysis for fish: the effectiveness of measure types in reducing pressures, links between existing measures and measure types, projected pressure reductions from existing measures, development of human activities, significance of pressures to state components and pressure reductions required to achieve GES/state improvements. The analysis assumes

that all existing measures are fully implemented and that there are no time lags between the input of pressures and environmental state.

Topic specific model structure, assumptions and challenges

Commercial fish uses 2018 as the base year for the population assessments based on the recommendation of topic experts but evaluates the effects of existing measures for the period of 2016-2030. Thus, measures affecting the state of commercial fish in 2016-2018 included in the SOM analysis may have at least partially already affected the state of fish populations. The implications of having different base years are likely minor for two reasons: 1) there are time lags in the recovery of these populations that indicate that measures implemented in 2016-2018 are unlikely to have had their full effect, and 2) no measures in the SOM analysis implemented prior to 2016 are expected to have sufficient time lags in their effects on the state of commercial fish to warrant inclusion in the analysis, indicating that the time frame for existing measures to be included in the analysis has not been artificially expanded.

The SOM approach has also struggled to accurately approximate the effect of dynamic management measures on fish stocks. This is further discussed in the section Lessons learned.

Overview of data

The SOM analysis for fish evaluates the sufficiency of measures in achieving GES or state improvements, considering the effects of existing measures and future development of human activities.

Table 2 shows the origin and spatial resolution for the data components in the SOM analysis for commercial fish. Activity-pressure contributions have not been assessed, all fish-specific pressures are created by a single activity (fishing) or are not dependent on activities but affect pressures or state directly (longitudinal connectivity of rivers). Information on existing measures comes from literature reviews and Contracting Parties, and development of human activities is based on existing literature, data and projections.

Estimates of the effectiveness of measures were collected both via expert surveys and a literature review for all topics included in the SOM analysis. The aim of the literature review was to compile information from scientific articles and reports providing estimates on the effects of measures in reducing pressures that could be used in the SOM analysis, either by including the estimates in the SOM model or by providing comparison points. The literature review was conducted by topic, with the information collected into structured excel files (see the methodology document, Annex 5 and Annex 6 for more information). For commercial fish, 248 effectiveness estimates from 76 studies were compiled. Out of these, 6 estimates from 4 studies could be included in the model. Scenarios for the development of human activities were based on existing information and projections for the Baltic Sea region, and pressure-state links were evaluated with expert elicitation.

The spatial resolution (level of detail) differs across the data components of the SOM analysis (Table 2). All areas are based on the 17 HELCOM scale 2 sub-basins and the assessment area

ranges from the single Baltic Sea to individual sub-basins. The activity-pressure contributions were not necessary for this topic as all fish specific pressures are created by a single activity (fishing) or are not activity dependent (longitudinal connectivity of rivers). The effectiveness of measure types in reducing pressures and the effect of development of human activities are assessed at the scale of the entire Baltic Sea. The spatial resolution for the pressure-state linkages varies across state components, from large sub-sections of the Baltic Sea to individual sub-basins. The definition of the state component may already include a geographic element, for example, the population of the species in a specific part of the Baltic Sea. Figures 2-5 present maps of the spatial coverage of each state component.

Table 2. Data for fish (more information on data collection is available in the methodology document)

Data component	Origin of data	Spatial resolution
Activity-pressure contributions	NA	NA
Existing measures	Literature review, Contracting Parties	17 sub-basins
Effectiveness of measures	Expert evaluation	Whole Baltic Sea
Development of human activities	Literature review, existing data and projections	Whole Baltic Sea
Pressure-state links	Expert evaluation	Various (Figures 2-5)

NA = not applicable

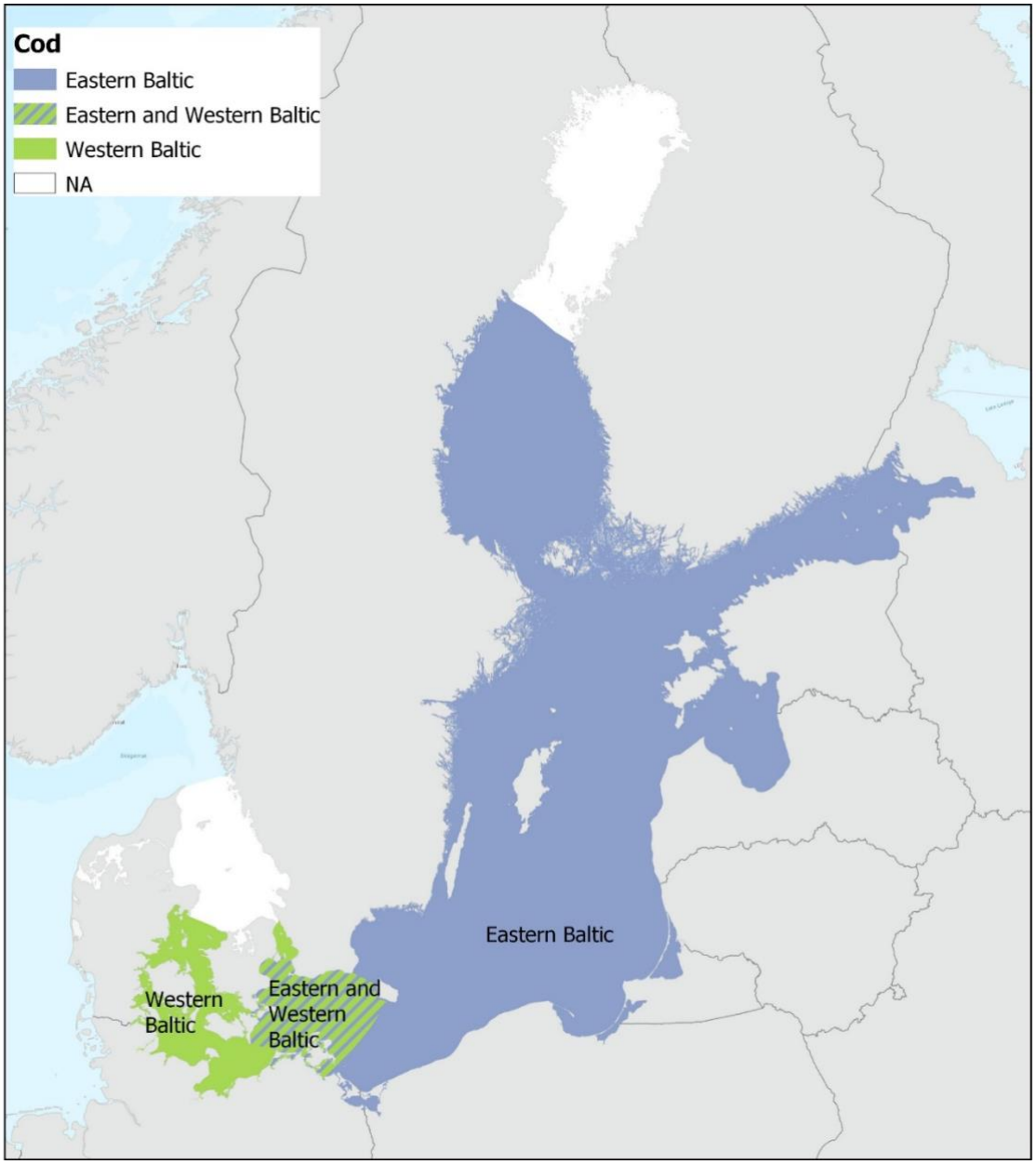

Figure 2. Spatial division of the Baltic Sea used in the state assessment of *Cod*. Areas correspond to ICES stock assessments, except that area 31 (Bothnian Bay and The Quark) has been excluded. Note that the Eastern and Baltic cod stocks overlap in the Arkona basin.

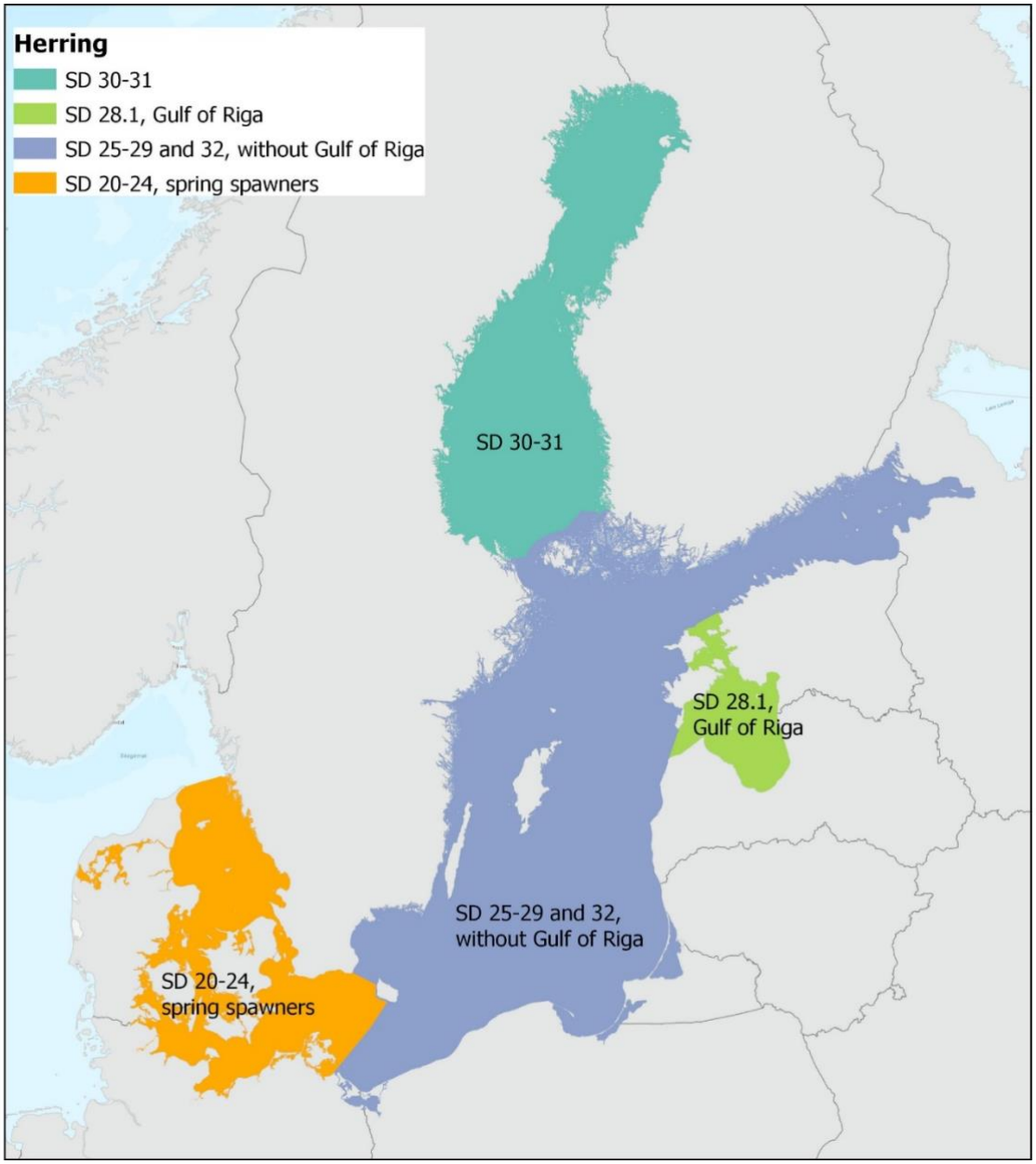

Figure 3. Spatial division of the Baltic Sea used in the state assessment of *Herring*. Areas correspond to ICES stock assessments.

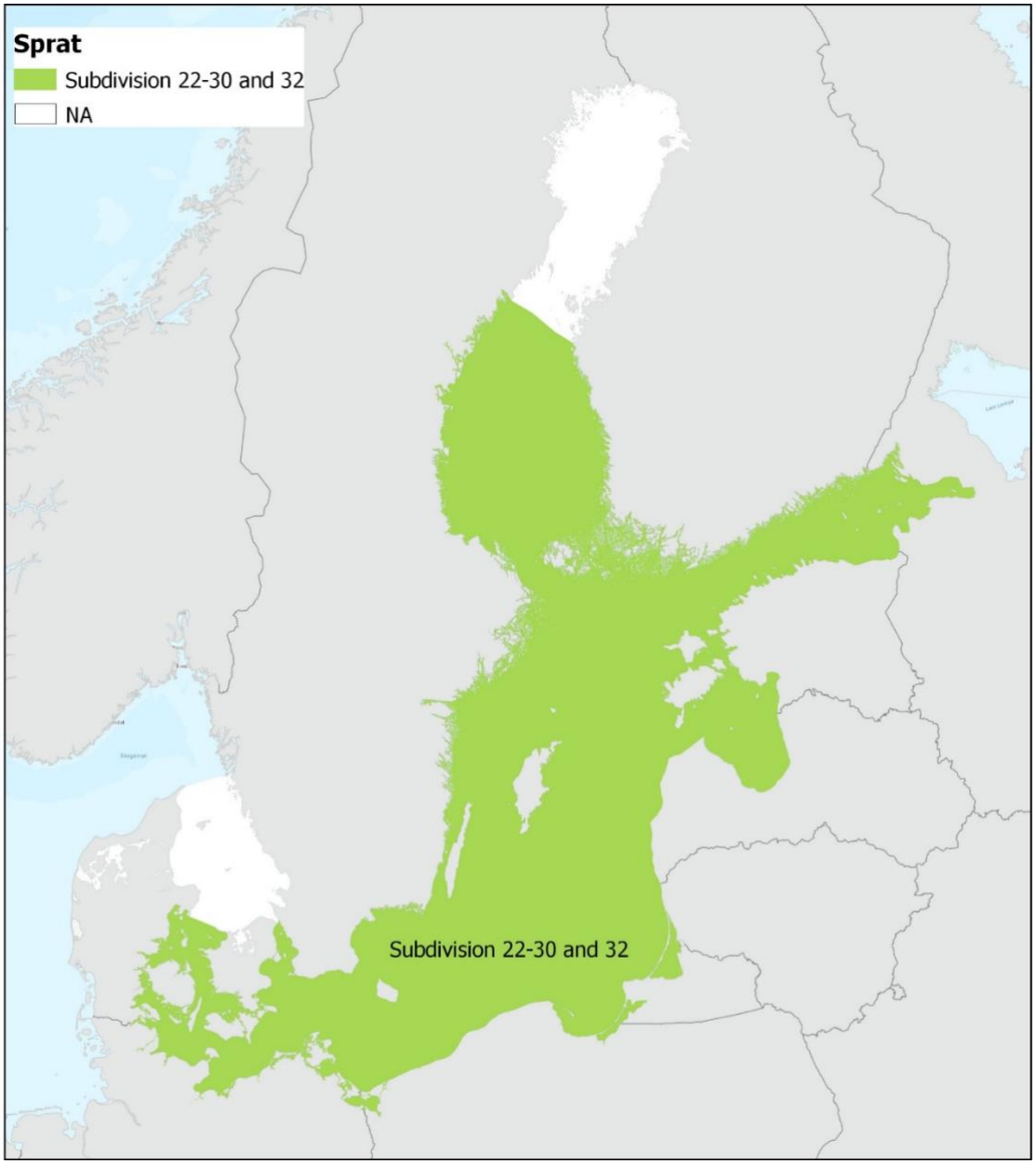

Figure 4. Spatial division of the Baltic Sea used in the state assessment of *Sprat*. Areas correspond to ICES stock assessments.

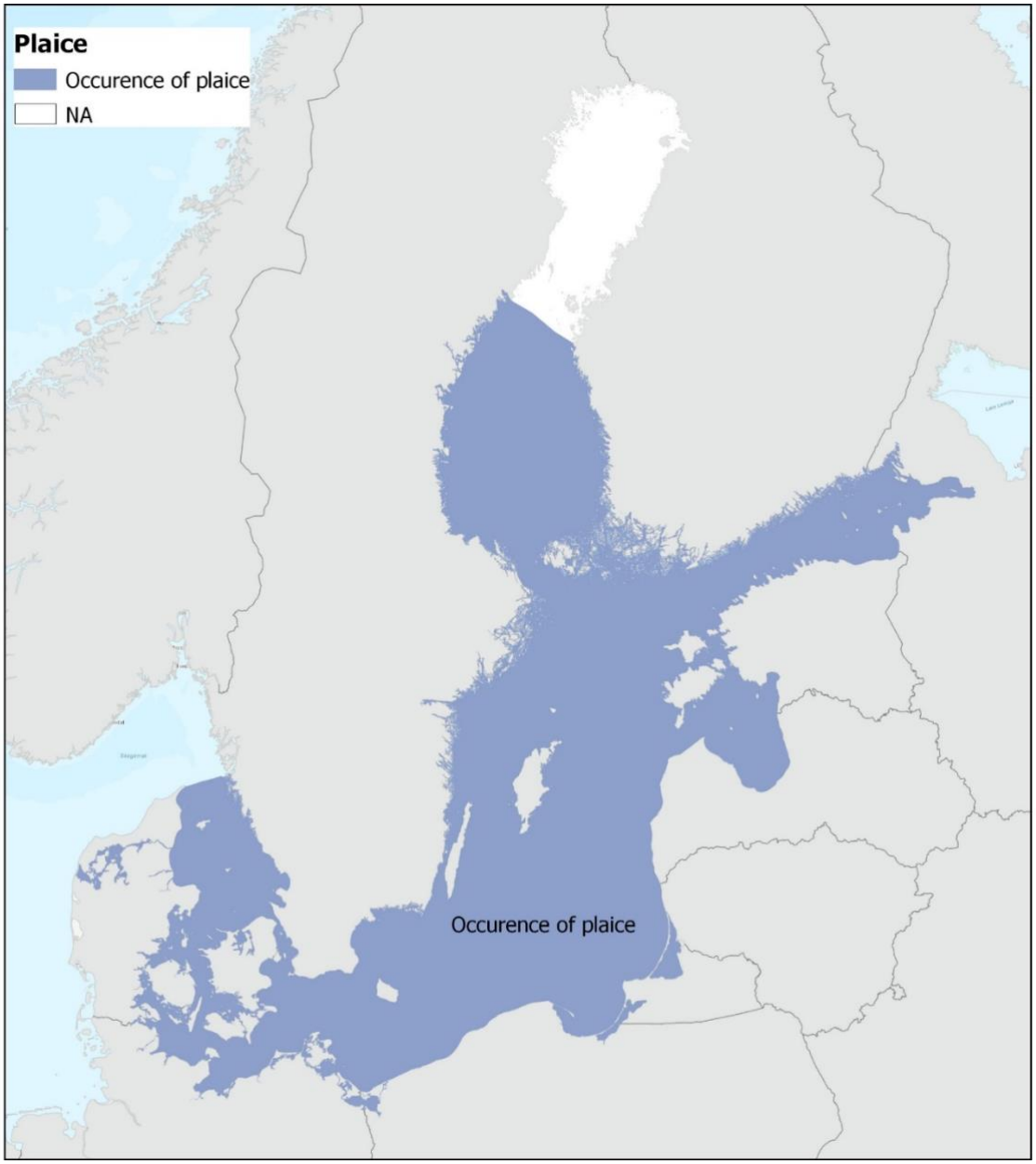

Figure 5. Spatial division of the Baltic Sea used in the state assessment of *Plaice*. Two separate ICES stocks are assessed here in a one-out-all-out protocol. Note area 31 (Bothnian Bay and The Quark) has been excluded.

Development of human activities

In addition to existing measures, changes in the extent of human activities may affect pressures over time. Four scenarios for future changes in human activities were developed: 1) no change, 2) low change, 3) moderate (most likely) change, and 4) high change. These alternative scenarios aim to capture uncertainties and variation in the future development of human activities. The results of the SOM analysis were estimated for each of the four scenarios to assess how the alternative assumptions on the development of human activities affect the findings. Detailed results are presented for the most likely development scenario, and implications of using the other scenarios on the results are reviewed in the discussion section.

The scenarios specify a percent change in each activity in 2016-2030 based on existing information and projections from the Baltic Sea region (see details and references in the methodology report). Change scenarios were made only for predominant activities in the Baltic Sea region, including agriculture, forestry, waste waters, (commercial) fish and shellfish harvesting, aquaculture, renewable energy production, tourism and leisure activities, transport shipping and transport infrastructure. Other activities are assumed to stay unchanged. This means that only 9 of the 31 standard SOM activities have change scenarios in the SOM analysis. This results in varying influence of these scenarios on the results across topics, pressures and state components, depending on the significance of the activities to the pressure inputs relevant to the topic.

Development scenarios have been made for fish and shellfish harvesting, which is the single activity that contributes to the targeted extraction and bycatch of commercial fish. However, in the most likely scenario, fishing is assumed to stay constant until 2030. The alternative low and high scenarios project a decrease and increase of 10% by 2030, respectively. More information on the development scenarios and source materials is given in section 9 of the methodology report.

The current situation with COVID-19 and its possible implications to the development of human activities is not reflected in the scenarios, as there is no information on the long-term effects it may have on the economy or activities. The current situation poses a challenge for choosing the most likely scenarios for the development of human activities, which has been done based on currently available information.

Results and interpretation

Background

The SOM results are presented in the format of percent shares or probabilities. The main finding of the analysis is the probability to achieve GES or specific state improvements/pressure input reductions, taking into consideration the effects of existing measures and changes in the activities on pressure inputs. The contribution of activities to pressure inputs, the effect of measures on pressure inputs, and the significance of pressures to state components are presented as percent values (e.g., how many percent would the measure reduce the pressure input). Results are presented mainly in tables, which show the most likely (expected) values and standard deviations. Standard deviation is a way of showing the variation in the values. When it is high, values are spread over a wider range, and when it is low, values are closer to the most likely value. Figures and graphs presenting distributions are included in the annexes. They show the same results as the tables but allow either more detailed information or alternative visualisation of the results.

For the data that are based on expert surveys, the confidence rating gives the most common answer to experts' assessment of the confidence in their own survey responses on a low-moderate-high scale. More detailed information on how each result has been calculated is presented in a separate document.

This document presents the detailed results based on the expert-based data (survey responses). Literature data on the effectiveness of measures has been collected and included in an alternative model estimation. The impacts of using the literature data are evaluated in the discussion section. In the detailed results, the projected development of human activities is based on the most likely future development until 2030 (for details, see the methodology document), and the impacts of alternative scenarios on human activities are examined in the discussion section.

Format of presentation

The format the results are reported in different ways (not presented, qualitative/semi-quantitative, quantitative) depending on the type of result and the number of participating experts. Further, for all results utilizing other SOM results as input data, reporting is done at the most conservative standard used in the input data. In practice this means that if one input data point is reported as 'insufficient data', all results using that data point will also be reported as 'insufficient data'; similarly for qualitative/semi-quantitative data points. However, note that this standard is only applied in the case of data points actively used to calculate another result. For example, many measure types are hypothetical or otherwise not implemented in the Baltic Sea and therefore do not factor into results on projected pressure input reductions from existing measures. Insufficient data for such measure types does not affect reporting other results that rely on data for effectiveness of measure types. Results that do not meet the data standards described here and in greater detail below are marked with 'insufficient data' in the report.

For results concerning required pressure reductions and significance of pressures to state components, results with 2 or fewer respondents are not reported; results with 3 to 4 respondents will be either not reported, or qualitatively/semi-quantitatively reported based on feedback from the SOM topic teams or other HELCOM expert body; results with 5 or more respondents are reported quantitatively. This standard allows flexibility for reporting on assessments that are of spatially limited areas and therefore have fewer experts available to survey, while also being somewhat conservative in reporting fully quantitative results. Based on input from the commercial fish topic team, results with 3 to 4 respondents will appear as ranges rather than fully quantified results.

For expert-based effectiveness of measures results, measure types with 5 or more respondents are reported quantitatively and those with 4 or fewer respondents are listed as having insufficient data.

For commercial fish, results on the sufficiency of measures in achieving GES for cod and plaice have been excluded, due to the lack of data to project the pressure reductions from existing measures. There is insufficient data on the effectiveness of many measure types, as less than 5 experts have contributed to the estimates. The other results for herring and sprat are presented, with the exception for results on the sufficiency of measures for herring in SD 28.1 (Gulf of Riga), which have been excluded due to lack of data. No activity-pressure expert data for commercial fish have been collected, because all fish-specific pressures are created by a single activity or are not dependent on activities but affect pressures or state directly.

Coverage of pressures in the SOM analysis

The SOM analysis has only been able to account for a portion of all pressures that affect the state components, and the effect of several significant pressures have not been included due to not being able to quantify the link between the pressure inputs, pressures and state components in the analysis. This means that the effect of reductions in these excluded pressures on the state components is not included in the total pressure reductions, and the projected total pressure reductions and probability to achieve GES are underestimated. The share of pressures covered in the analysis has been calculated based on the significance of pressures to the state component in question. The share varies across topics and state components from low (around 20%) to high (more than 80%).

Are existing measures sufficient for achieving or maintaining good status?

For herring, the SOM analysis evaluates whether existing measures are sufficient in achieving or maintaining GES by comparing the state improvement from existing measures to the state improvement required to achieve GES for SD 20-24 and SD 25-29 and 32. For SD 30-31, the analysis assesses the sufficiency of measures in achieving specific state improvements (10, 25 and 50% improvement in the abundance of fish). For sprat, the analysis evaluates whether existing measures are sufficient in maintaining GES for SD 22-30 and 32. In the ICES stock assessments used as the base year for this analysis (2018; ICES (2019a-j)), four of the stocks were in good status based on SSB: herring in SD 25–29 and 32, excluding the Gulf of Riga, herring in SD 28.1 (Gulf of Riga), sprat in SD 22-30 and 32, and

plaice. The probability to maintain GES was assessed as relatively high for herring in SD 25–29 and 32 and sprat in SD 22-30 and 32, according to the expert survey. Results for plaice and herring in the Gulf of Riga are excluded due to insufficient data.

Overall, the results indicate that the probability to achieve or maintain GES or state improvements for commercial fish with existing measures depends on the species and area (Table 3). Reductions in total pressures are moderate (15-30%) for both herring and sprat. The probability to achieve GES for herring is close to zero for SD 20-24, but the probability to maintain GES, in relation to the SSB indicator, is high in SD 25-29 and 32. For sprat, probability of maintaining GES in SD 22-30 and 32 is moderate. Results for cod, plaice and herring in the Gulf of Riga are excluded due to insufficient data.

In the case of commercial fish, the SOM analysis has been able to account for 43-56% of the pressures linked to the state components (pressures highlighted in white in Table 6). This percent reflects the share of pressures that 1) have a quantifiable link to the fish state components and 2) have measures types that affect them in the SOM analysis. It has been calculated based on the significance of pressures affecting commercial fish (Table 6) and represents the maximum pressure reduction that could be achieved if the pressures linked to commercial fish species in the SOM analysis were eliminated. The effects of several significant pressures are not included in this total, such as effects of eutrophication, change in hydrologic conditions and human-induced food web imbalance (pressures highlighted in grey in Table 6). Although some of these pressures are expected to decrease based on the results of the SOM analysis, the analysis is not able to estimate how this would affect the state of commercial fish. Thus, the total pressure reductions and probability to achieve GES/state improvements are underestimated.

Table 3 shows the expected total pressure reductions from existing measures, the probability to achieve GES or a specific state improvement with such a pressure reduction, and the maximum pressure reduction that could be achieved with the fully quantified pressures in the SOM analysis. Total pressure reductions are calculated based on the reduction in the pressures affecting commercial fish (Table 8), significance of different pressures to commercial fish (Table 6), and spatial weighting to account for the target area of existing measures. The format of the results depends on whether an established HELCOM GES threshold exists for the state component (species and geographic area) in question. Results with 2 or fewer responding experts are not shown due to insufficient data.

For *herring*, the expected total pressure reduction from existing measures in the Baltic Sea is moderate in all areas (15-30%), and the findings suggest that the probability to achieve GES is close to zero for SD 20-24 but relatively high for SD 25-29 and 32. In SD 30-31, the probability to achieve a 10% state improvement with existing measures is assessed as high. Results for the Gulf of Riga are excluded due to insufficient data. The findings for sprat suggest that the expected pressure reductions range from 15 to 25%, which results in a moderate probability to maintain GES In SD 22-30 and 32. Results on total pressure reductions and probability to achieve state improvements for *cod* and *plaice* are not presented due to insufficient data.

Table 4 presents the total pressure reduction required to reach/maintain GES or a specific state improvement for each fish species by sub-area, based on the expert responses. The required pressure reduction to achieve GES for herring ranges between 20% and 70%, depending on the area. For cod, the required pressure reduction to achieve GES is estimated

to be around 50-80%. For sprat, pressure reductions of around 20% are required to achieve GES. For plaice, required pressure reductions are around 10%. There is considerable uncertainty about the required pressure reductions to achieve GES/state improvements, and the certainty of the estimates ranges from low to high. Expert's confidence in their own responses to the question on total pressure reduction required is low or high for herring, high for cod, moderate-high for sprat and high for plaice.

Distributions of expert responses on the required pressure reductions to achieve GES/state improvements are included in Annex 10. The figures indicate that there is substantial uncertainty about the required pressure reductions (wide distributions). Thus, these graphs provide further evidence that there is considerable uncertainty about the link between pressure reductions and achieving improvements in state.

Table 3. Sufficiency of measures in achieving GES or specific state improvements for commercial fish. The table presents the expected values and the 10-90 percentile in brackets, which shows the range in which 80% of the observations fall in. When a GES threshold exists, the result shows the probability to achieve GES with expected pressure reduction. When there is no GES threshold, the table shows the probability to achieve a specific state improvement (10%, 25% and 50%) with expected pressure reduction.

State	**Assessment area**	**Total pressure reduction (%)** [10 percentile – 90 percentile]	**Probability to achieve GES (%) with expected pressure reduction** [10 percentile – 90 percentile]	**Probability (%) to achieve specific state improvement with expected pressure reduction** [10 percentile – 90 percentile]			**Maximum possible pressure reduction due to model coverage (%)**
				10% state improvement	**25% state improvement**	**50% state improvement**	
Herring	SD 20-24, spring spawners	23 [16-29]	0 [0-0]				47
	SD 25–29 and 32, excluding the Gulf of Riga	19 [13-24]	58 [43-67]				56
	SD 28.1 (Gulf of Riga)	Insufficient data					
	SD 30-31	20 [14-26]		64 [25-83]	2 [0-18]	1 [0-4]	47
Cod	Western Baltic	Insufficient data					
	Eastern Baltic	Insufficient data					
Sprat	SD 22–30 and 32	18 [13-23]	38 [24-46]				43
Plaice	Baltic Sea, excluding the Quark and Bothnian Bay	Insufficient data					

Data used: expert estimates of effectiveness of measure types, information on existing measures, expert estimates of significance of pressures to state components, expert estimates of required pressure reductions to achieve GES, information and projections on development of human activities.

Table 4. Total pressure reduction required to maintain or reach GES (herring, cod, plaice) or achieve specific state improvements for commercial fish (herring, SD 30-31). Standard deviation is given in parentheses. Confidence depicts the most common rating of expert's confidence in their own responses to the question on total pressure reduction required to reach GES/specific state improvements. The following populations are already in good status: herring SD 25-29, 32 (excl. Gulf of Riga), herring SD 28.1 (Gulf of Riga), sprat SD 22-30, 32, and plaice.

State	**Herring SD 20-24, spring spawners**	**Herring SD 25-29, 32 (excl. Gulf of Riga)**	**Herring SD 28.1 (Gulf of Riga)**
Most likely pressure reduction required (%)	67 (16) ●●●	20 (22) ○○●	Insufficient data
Confidence	High	High	NA
Number of experts	9	13	Less than 3
State	**Herring SD 30-31**		
	10% state improvement	**25% state improvement**	**50% state improvement**
Most likely pressure reduction required (%)	19 (9) ○●●	49 (10) ●●●	66 (23) ○●●
Confidence	Low	Low	Low
Number of experts	8	7	8
State	**Cod, Western Baltic**	**Cod, Eastern Baltic**	
Most likely pressure reduction required (%)	52 (14) ●●●	76 (18) ●●●	
Confidence	High	High	
Number of experts	10	18	
State	**Sprat SD 22-30, 32**		
Most likely pressure reduction required (%)	21 (21) ○○●		
Confidence	High - Moderate		
Number of experts	16		
State	**Plaice**		
Most likely pressure reduction required (%)	12 (15) ○○●		
Confidence	High		
Number of experts	6		

Colour scale for the percent reduction in pressures required to reach GES in percent (based on the expected value):
0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Categories for the certainty of the reduction required estimate (based on the relative size of the standard deviation to the expected value): low: ○○●, moderate: ○●●, high: ●●●
NA= not applicable
Data used: expert estimates of required pressure reductions to achieve GES/state improvements

What are the time lags between pressure and state?

Information on time lags between pressures and state of commercial fish was collected from experts, who evaluated how long it would take to achieve GES assuming sufficient measures were implemented. Table 5 shows the distribution and average of the answers for commercial fish.

The average time lags between pressure reductions and state are projected to be relatively short for herring, sprat and plaice (2-7 years). The time lags are somewhat longer for cod (10-16 years). The factors reported to contribute to the time lags for herring and sprat were long population recovery times caused by their life cycle, recovery time for food webs, as well as hydrological conditions, and effects from climate change. For cod, in addition to these factors, also eutrophication was stated to contribute to time lags. For plaice, population recovery times and degraded seafloor were considered to affect time lags.

Table 5. Time lags in achieving GES with sufficient measures for commercial fish. Responses with clear reference to time lags due to lags in the implementation of measures have been excluded. The values in the row 'Number of experts' includes experts with excluded responses.

Time lag	Herring				Sprat	Cod		Plaice
	SD 20-24, *spring spawners*	**SD 25-29, 32 *(excl. Gulf of Riga)***	**SD 28.1 *(Gulf of Riga)***	**SD 30-31**	**SD 22-30, 32**	**Western**	**Eastern**	**Plaice**
0 years (no time lag)	0	0	Insufficient data (less than 3 experts)	0	0	0	0	5
0-5 years	1	12		6	13	0	0	2
6-10 years	8	3		1	2	7	5	1
11-25 years	0	0		0	0	2	11	0
26-50 years	0	0		0	0	0	1	0
51-100 years	0	0		0	0	0	0	0
More than 100 years	0	0		0	0	0	0	0
Excluded	0	0		1	1	1	1	0
Average	6.9	3.5		3.2	3.2	9.7	15.7	1.6
SD	1.6	2		1.8	1.7	4.2	7.1	2.5
Confidence	High	High		High	High	Moderate	High	High
Number of experts	9	15		8	16	10	18	8

Data used: expert estimates of time lags.

What are the pressures contributing to the state components?

Tables 6.1 and 6.2 show the significance of pressures affecting commercial fish (herring, cod, sprat, plaice). They enable comparison across species and geographic areas. Overall, 12 different pressures are significant to commercial fish. The most significant pressure to all species is the *extraction of fish*. In addition, *human-induced food web imbalance* and *change in hydrologic conditions* are among the most significant pressures. *Effects of eutrophication* are also important, particularly to cod.

Experts' confidence in their own responses to the significance of pressures question was high. Results with 2 or fewer responding experts are not shown due to insufficient data.

Inclusion of change in hydrologic conditions in the list of significant pressures is unexpected. It may be that experts were attributing all or a portion of the effects of eutrophication or climate change to this pressure.

Table 6.1. Significance of pressures (%) affecting herring.

State Pressure	Herring			
	SD 20-24, spring spawners	**SD 25–29 and 32, excluding the Gulf of Riga**	**SD 28.1 (Gulf of Riga)**	**SD 30-31**
Extraction of fish (includes prey depletion)	37	34	Insufficient data	39
Species disturbance or displacement by human presence	6	3		8
Species disturbance: obstructions and collisions		3		
Effects of non-indigenous species		1		3
Physical disturbance of marine habitats		9		5
Physical loss of marine habitats	10	10		3
Effects of eutrophication	19	9		11
River, lake, or land habitat loss/degradation	3			
Change in hydrologic conditions	21	10		8
Human-induced food web imbalance	4	20		24
Confidence	High	High	NA	High
Number of experts	9	13	Less than 3	8

Colour scale for the significance of the pressure to the state variable (based on the expected value):
0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Pressures for which we cannot quantify the link between the pressure input, pressure and state in the SOM analysis are highlighted in grey, e.g. we cannot link reductions in nutrient inputs to reductions in the effects of eutrophication and further to abundance of fish.
NA = not applicable
Data used: expert estimates of significance of pressures to state components

Table 6.2. Significance of pressures (%) affecting cod, sprat, plaice.

State	Cod		Sprat	Plaice
Pressure	Western Baltic	Eastern Baltic	SD 22–30 and 32	Occurrence of Plaice
Bycatch in ghost nets		3		
Extraction of fish (includes prey depletion)	28	26	37	50
Species disturbance or displacement by human presence	4		4	
Effects of non-indigenous species			1	
Physical disturbance of marine habitats	2	8	3	6
Physical loss of marine habitats	7	7	3	8
Effects of eutrophication	26	21	13	19
Radioactive pollution		3		
Change in hydrologic conditions	17	16	19	6
Human-induced food web imbalance	16	16	20	11
Confidence	High	High	High	High
Number of experts	10	19	16	6

Colour scale for the significance of the pressure to the state variable (based on the expected value):
0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Pressures for which we cannot quantify the link between the pressure input, pressure and state in the SOM analysis are highlighted in grey, e.g. we cannot link reductions in nutrient inputs to reductions in the effects of eutrophication and further to abundance of fish.
Data used: expert estimates of significance of pressures to state components.

What are the state components most affected by fishing?

The data from the pressure-state expert surveys for hazardous substances, benthic habitats, birds, fish and mammals allow the state components most affected by pressures related to fishing to be identified. These five expert surveys provide expert views on the significance of various pressures to the state components in the SOM analysis. The most affected state components are identified based on the percent contribution of different pressures to the state component. First, the average percent significance of pressures has been calculated by state component, and then the pressures having the highest averages have been identified. This approach will overemphasize pressures important to geographically smaller assessment areas and may impact the rankings, as no corrections to account for the sizes of the assessment areas have been applied.

Table 7 shows the state components most affected by the extraction of fish and bycatch in fishing gears. State components most affected by bycatch in fishing gears are bird species and harbour porpoise. The extraction of fish most impacts some species of commercial and coastal fish.

Table 7. Top five state components most affected by pressures related to fishing. Listing is based on Baltic-wide averages of the significance of pressures to state components presented in each respective topic report. Average number of expert responses for the state component is given in parenthesis (total response count for the state component divided by the number of geographic areas for the state component).

Pressure	1st most affected state component	2nd most affected state component	3rd most affected state component	4th most affected state component	5th most affected state component
Extraction of fish (includes prey depletion)	Plaice (6.0)	Flounder (4.3)	Herring (7.8)	Sprat (16.0)	Perch and other coastal piscivores (4.8)
Bycatch in fishing gears (for birds and mammals only; excludes ghost nets)	Red-throated diver (6.0)	Long-tailed duck (7.0)	Harbour porpoise (3.0)	Great cormorant (9.0)	

Less than five most affected state components are presented in cases where there is insufficient data for some state component(s) affected by the pressure, i.e. there are not enough expert responses to the significance of pressures to the state component in the survey (e.g. some mammals species). This corresponds to the criteria for the format of presentation.
Data used: expert estimates of significance of pressures to state components for all topics.

What are the reductions in pressures from existing measures?

Table 8 shows the effects of existing measures in reducing the pressures on commercial fish at the scale of the Baltic Sea in 2016-2030, considering the changes in the extent of human activities. They are calculated using the data on effectiveness of measure types, links between existing measures and measure types, and projected development of human activities.

As the effectiveness of measures data are at the Baltic Sea level, the total pressure reductions are presented as an average for the entire Baltic Sea.

The *targeted extraction and bycatch of pelagic fish* is projected to be reduced to a rather high extent at the Baltic Sea scale. In the further analysis, this estimate has been applied to herring and sprat. The certainty of the estimate is evaluated as high. There is insufficient data to present the estimates for cod and flatfish (plaice) due to lack of data on the effectiveness of measure types (Table 9).

The projected pressure reduction in targeted extraction and bycatch is based only on the estimated effects of existing measures, as fish and shellfish harvesting is projected to stay constant until 2030 in the most likely development scenario for human activities.

Further details on the effectiveness of different measure types can be found in Table 9.

Table 8. Projected pressure reductions (%) from existing measures on commercial fish in 2016–2030. The table depicts the most likely/expected values of total pressure reductions and gives standard deviation in parenthesis. Projected reductions are presented as the weighted average of each assessment unit for each listed taxonomic grouping.

Pressure	Targeted extraction and bycatch		
Area	Cod	Flatfish	Pelagic fish
Baltic Sea	Insufficient data	Insufficient data	45 (9) ●●●

Colour scale for the pressure reductions in percent (based on the expected value):
0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Categories for the certainty of the pressure reductions (based on the relative size of the standard deviation to the expected value):
low: ○○●, moderate: ○●●, high: ●●●
Data used: expert estimates of effectiveness of measure types, information on existing measures.

How effective are measure types in reducing pressures?

This section presents the percent effectiveness of measure types in reducing the *targeted extraction and bycatch of commercial fish*. The estimates are presented per activity, i.e. they portray the percent reduction in the pressure from the activity in question, and not in the total pressure across all activities. Information on the reductions over all activities contributing to the pressure is given in the section on the impacts of measure types. Data on the effectiveness of measure types originate from expert surveys and are at the Baltic Sea scale.

The effectiveness estimates can be compared across measure types to assess, on average, how effective they are in relation to each other in reducing the pressure from the specific activities, or across activities to assess which measure type could be the most effective for each activity. Results with 4 or fewer responding experts are excluded due to insufficient data.

Seasonal and spatial closures appear among the most effective measure types to reduce *targeted extraction and bycatch of commercial fish* from *fish and shellfish harvesting* (Table 9). Several other measure types also have a high average effectiveness, such as *technical measures to reduce catches of unwanted species or sizes of fish*. There is insufficient data on the effectiveness of several measure types for cod and flatfish.

Overall, there is considerable uncertainty about the effectiveness of most measure types based on the standard deviations. The certainty of the estimates varies from low to high. Experts' confidence in their estimates is high.

Estimates of the effectiveness of measure types are used to assess the effects of existing measures in reducing the pressures to commercial fish and to calculate pressure reductions from existing measures by 2030.

Table 9. Effectiveness of measure types (%) in reducing the *targeted extraction and bycatch of fish* from fish and shellfish harvesting (all gears, professional and recreational) for commercial fish (cod, flatfish, and pelagic). The effectiveness of a measure type is the percent reduction in the pressure resulting from a specific activity. The table depicts the expected values of effectiveness, and standard deviation is given in parenthesis. Estimates are presented by species/species group. If the measure type has an existing measure(s) that covers less than all the assessed species/species group, the species/species group with existing measures are listed in the column 'Has corresponding existing measures in the SOM analysis'.

Measure type ID	Species Measure type	Cod	Flatfish	Pelagic fish	Has corresponding existing measures in the SOM analysis (Yes/No)
101	Seasonal closures	Insufficient data	Insufficient data	66 (23) o●●	No
102	Spatial closures	65 (18) ●●●	72 (15) ●●●	68 (27) o●●	No
103	Technical measures to reduce catches of unwanted species	46 (19) o●●	60 (8) ●●●	54 (18) o●●	No
104	Technical measures to reduce catches of unwanted sizes of fish	56 (18) o●●	38 (19) o●●	34 (24) oo●	No
106	Measures to reduce recreational fishing (e.g. licenses)	34 (24) oo●	Insufficient data	16 (23) oo●	No
107	Measures to reduce commercial fishing capacity	25 (27) oo●	57 (16) ●●●	61 (16) ●●●	No
108	Catches of commercial fish in line with targets for MSY	49 (28) o●●	42 (21) o●●	55 (19) o●●	No
109	Bag limits (e.g. daily/seasonal) in recreational fisheries	Insufficient data	Insufficient data	14 (20) oo●	No
110	Ensure compliance with existing regulations (commercial and/or recreational)	55 (26) o●●	55 (16) ●●●	52 (21) o●●	No
111	Promotion of sustainable fisheries (commercial and/or recreational)	31 (18) o●●	32 (19) oo●	50 (20) o●●	Yes
112	CFP multi-annual plan	Not assessed	35 (17) o●●	54 (17) o●●	Yes (Pelagic fish)
141	Unspecified MPA fisheries restrictions	Insufficient data	Insufficient data	42 (16) o●●	Yes
	Confidence	High	High	High	
	Number of experts	5-6	5-6	5-7	

Colour scale for the effectiveness of a measure type in percent (based on the expected value): 0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Categories for the certainty of the effectiveness estimate (based on the relative size of the standard deviation to the expected value): low: oo●, moderate: o●●, high: ●●●
Data used: expert estimates of effectiveness of measure types.

Which activities contribute to pressures?

The activity-pressure contributions were not estimated for fish, as all fish specific pressures are created by a single activity (fishing) or are not dependent on activities but affect pressures or state directly (longitudinal connectivity of rivers).

What are the impacts of measure types?

The impacts of measure types show the impact of measure types on reducing the targeted extraction and bycatch of commercial fish. They include the effectiveness of measure types and the contribution of activities to pressure. Thus, the impact shows how much the measure type reduces the pressure across all activities contributing to the pressure and give indications on which measures could be the most relevant in addressing specific pressures.

In the case of commercial fish, the effectiveness and impacts of measure types are the same, as the pressures originate from a single activity (fish and shellfish harvesting). The most impactful measures to reduce the targeted extraction and bycatch of commercial fish are those related to spatial and seasonal closures, as well as technical measures to reduce catches of unwanted species or sizes of fish. Several other measure types are assessed to have relatively large impacts, and the uncertainty about the impacts is rather high, as visible in the standard deviations.

What are the impacts of existing measures?

This section presents information about existing measures affecting commercial fish. In the SOM analysis, existing measures are those measures in current policy frameworks (e.g. BSAP, EU MSFD, EU WFD, EU Biodiversity Strategy 2020) that affect pressures and environmental state within the time frame of the analysis (2016-2030). This includes measures that have been implemented, are partially implemented or are planned to be implemented by 2030. Measures which have already been fully implemented and have fully affected pressures and environmental state by 2016 have been excluded, as no further improvement of status is expected during in 2016-2030. Information about existing measures was compiled through a literature review and from Contracting Parties.

The impact is the percent reduction in a specific pressure from implementing the measure in the relevant spatial area. It has been calculated based on the effectiveness of the measure, proxied by the effectiveness of the measure type it corresponds to, and the contribution of activities to the pressure in question. Similar to the impact of a measure type, the impact of an existing measure indicates how much the measure reduces the pressure across all activities contributing to the pressure.

Tables 10 present the impacts of existing measures in reducing the targeted extraction and bycatch of commercial fish (cod, flatfish, pelagic fish). The impacts are presented both for the Baltic Sea scale and for the area affected by the existing measure. In addition, information on the share of the Baltic Sea area affected by the existing measure is included. Both the effectiveness of the measure and the spatial area affected are relevant for the impact at the Baltic Sea scale. Some existing measures may have high impact in the affected area, but their impact at the Baltic Sea scale is low because they only affect a small area, while some measures may have a relatively low impact in the affected area but affect a large share of the Baltic Sea.

There are altogether five existing measures affecting the targeted extraction and bycatch of cod, five of flatfish, and six of pelagic fish in the SOM analysis. Most existing measures have a relatively high impact in

the area affected but low impact at the scale of the Baltic Sea, as the area affected is limited. The only exception is the multiannual plan for cod, herring and sprat, which applies to almost the entire Baltic Sea and has a high impact at the Baltic Sea scale.

Table 10. Impacts of existing measures in reducing the targeted extraction and bycatch of commercial fish (cod, flatfish, pelagic fish). Impact is the percent reduction in a specific pressure from implementing the measure. Measure name and description correspond to those used in Annex 4 for referencing purposes. In rare cases, the name and description may not be representative of the existing measure due to the free text reporting format used during existing measures data collection. Standard deviations are given in parenthesis. Note that values less than 0.5 have been rounded to zero.

Species	Measure name	Description	Activities	Countries	Measure type	Impact at the Baltic Sea scale (%)	Impact in the area affected (%)	Affected area of the total Baltic Sea (%)
Cod	Continue to raise public awareness of sustainable, ecosystem-compatible fisheries (UZ4-01, M411)	Further anchoring of the topic "sustainable eco-system-appropriate fishing" in public awareness	Fishing	DE	Promotion of sustainable fisheries (commercial and/or recreational)	1 (1)	32 (17)	4
Cod	BALDE-M919-other	Fisheries management measures in Natura 2000 sites in the EEZ	Fishing	DE	Unspecified MPA fisheries restrictions	0 (0)	37 (15)	0
Cod	BALDE-M412-UZ4-02	Fisheries measures	Fishing	DE	Promotion of sustainable fisheries (commercial and/or recreational)	0 (0)	32 (17)	0
Cod	BALDE-M412-UZ4-02	Fisheries measures	Fishing	DE	Unspecified MPA fisheries restrictions	0 (0)	36 (15)	0
Cod	Fisheries measures (M412-UZ4-02)	o Fisheries management measures in Natura 2000 sites. Germany will develop 'common advices' for necessary fisheries restrictions in these areas, which will be developed with the federal states, stakeholders from the fisheries industry and NGOs involved in fisheries management o MSFD targets considered when developing the federal fisheries policies	Fishing	DE	Unspecified MPA fisheries restrictions	0 (0)	36 (15)	0

Species	Measure name	Description	Activities	Countries	Measure type	Impact at the Baltic Sea scale (%)	Impact in the area affected (%)	Affected area of the total Baltic Sea (%)
Flatfish	Continue to raise public awareness of sustainable, ecosystem-compatible fisheries (UZ4-01, M411)	Further anchoring of the topic "sustainable eco-system-appropriate fishing" in public awareness	Fishing	DE	Promotion of sustainable fisheries (commercial and/or recreational)	1 (1)	31 (19)	4
Flatfish	BALDE-M919-other	Fisheries management measures in Natura 2000 sites in the EEZ	Fishing	DE	Unspecified MPA fisheries restrictions	0 (0)	33 (14)	0
Flatfish	BALDE-M412-UZ4-02	Fisheries measures	Fishing	DE	Promotion of sustainable fisheries (commercial and/or recreational)	0 (0)	31 (19)	0
Flatfish	BALDE-M412-UZ4-02	Fisheries measures	Fishing	DE	Unspecified MPA fisheries restrictions	0 (0)	34 (14)	0
Flatfish	Fisheries measures (M412-UZ4-02)	o Fisheries management measures in Natura 2000 sites. Germany will develop 'common advices' for necessary fisheries restrictions in these areas, which will be developed with the federal states, stakeholders from the fisheries industry and NGOs involved in fisheries management o MSFD targets considered when developing the federal fisheries policies	Fishing	DE	Unspecified MPA fisheries restrictions	0 (0)	33 (14)	0

Species	Measure name	Description	Activities	Countries	Measure type	Impact at the Baltic Sea scale (%)	Impact in the area affected (%)	Affected area of the total Baltic Sea (%)
Pelagic fish	Cod, herring, sprat multiannual plan	Article 4 Targets 1. The target fishing mortality shall be achieved as soon as possible and, on a progressive, incremental basis, by 2020 for the stocks concerned, and it shall be maintained thereafter within the ranges set out in Annex I and in line with the objectives laid down in Article 3(1). Article 5 Safeguards 1. The conservation reference points expressed as minimum and limit spawning stock biomass levels that are to be applied in order to safeguard the full reproductive capacity of the stocks concerned are set out in Annex II.	Fishing	EU countries	CFP multi-annual plan	50 (12)	53 (12)	94
Pelagic fish	Continue to raise public awareness of sustainable, ecosystem-compatible fisheries (UZ4-01, M411)	Further anchoring of the topic "sustainable eco-system-appropriate fishing" in public awareness	Fishing	DE	Promotion of sustainable fisheries (commercial and/or recreational)	2 (1)	50 (19)	4
Pelagic fish	BALDE-M919-other	Fisheries management measures in Natura 2000 sites in the EEZ	Fishing	DE	Unspecified MPA fisheries restrictions	0 (0)	41 (16)	0
Pelagic fish	BALDE-M412-UZ4-02	Fisheries measures	Fishing	DE	Promotion of sustainable fisheries (commercial and/or recreational)	0 (0)	50 (20)	0
Pelagic fish	BALDE-M412-UZ4-02	Fisheries measures	Fishing	DE	Unspecified MPA fisheries restrictions	0 (0)	41 (16)	0

Species	Measure name	Description	Activities	Countries	Measure type	Impact at the Baltic Sea scale (%)	Impact in the area affected (%)	Affected area of the total Baltic Sea (%)
Pelagic fish	Fisheries measures (M412-UZ4-02)	o Fisheries management measures in Natura 2000 sites. Germany will develop 'common advices' for necessary fisheries restrictions in these areas, which will be developed with the federal states, stakeholders from the fisheries industry and NGOs involved in fisheries management o MSFD targets considered when developing the federal fisheries policies	Fishing	DE	Unspecified MPA fisheries restrictions	0 (0)	41 (16)	0

Data used: information about existing measures and their spatial scale, expert estimates of effectiveness of measures types.

Full activity names:

- Fish and shellfish harvesting (all gears; professional, recreational)

Background of respondents

For the effectiveness of measures survey for fish (common for coastal, commercial and migratory fish), altogether 24 survey responses with 37 contributing experts were received. Six of the answers were group responses with two to eight contributing experts. The commercial fish portion of the effectiveness of measure survey had altogether 9 survey responses and 18 contributing experts (with two group responses from four to eight experts each). For the pressure-state surveys, 14 responses from 21 experts were received. Several group responses were received for the pressure-state surveys (three responses with two to five contributing experts, depending on the sub-topic).

The number of experts contributing to the fish surveys is shown in Table 10, with the sub-topic division and geographic area presented in Table 11.

Table 10. Number of experts contributing to the fish surveys.

Survey	DE	DK	EE	FI	LT	LV	PL	RU	SE	Total
Effectiveness of measures (all fish groups)	5	5	3	6	2	-	3	-	13	37
Effectiveness of measures (commercial fish)	-	5	-	2	1	-	1	-	9	18
Pressure-state linkages (commercial fish)	4	5	-	1	2	-	3	-	6	21

Table 11. Number of responses to the fish surveys

Survey	Sub-topic	Geographic area	Response count
Effectiveness of measures		Whole Baltic	36
Pressure-state (commercial fish)	Herring SD 20-24, spring spawners		9
	Herring SD 25-29, 32 (excluding Gulf of Riga)		14
	Herring SD 28.1 (Gulf of Riga)		1
	Herring SD 30-31		8
	Sprat SD 22-30, 32		16
	Cod, western		10
	Cod, eastern		19
	Plaice		7

More detailed information is available for the experts participating in the effectiveness of measures and the pressure-state surveys. Experts stated most often fish research and fisheries as their respective field, followed by aquatic sciences, marine ecology and conservation. For both surveys, more than half of the experts had 10-20 or over 20 years of experience (Table 12). Experts represented research institutions, NGOs, or ministries.

Table 12. Years of experience in the field for the commercial fish surveys

	Effectiveness of measures		Pressure-state (commercial fish)	
Years of experience	**Number of experts**	**Share of experts**	**Number of experts**	**Share of experts**
0-2 years	1	3 %	1	5 %
3-5 years	3	8 %	2	10 %
5-10 years	10	27 %	4	19 %
10-20 years	10	27 %	7	33 %
over 20 years	13	35 %	7	33 %

Discussion

Impact of alternative scenarios for development of human activities

The detailed results are presented for the most likely development scenario for the extent of human activities in 2016-2030. In addition, three other development scenarios were estimated: no change, low change and high change scenarios. These scenarios cover 9 out of the 31 activities in the SOM analysis. The extent of other activities is assumed to remain constant in all scenarios.

As activities contribute to pressures, their assumed change over time affects the pressure reductions and probability to achieve state improvements. The impact depends on to what extent the activities contributing to the specific pressure are covered in the change scenarios. For commercial fish, the only activity that contributes to the targeted extraction and bycatch of fish is fish and shellfish harvesting, and it is covered in the change scenarios. In the most likely scenario, no changes in the extent of fishing are projected until 2030. The alternative low and high scenarios project a decrease and increase of 10% by 2030, respectively.

Overall, the impact of alternative development scenarios on projected pressure reductions is not very significant for commercial fish, as the projected changes in fish and shellfish harvesting by 2030 are relatively small in both the low and high scenarios. Decrease in fish and shellfish harvesting results in somewhat larger pressure reductions for pelagic fish, while increase leads to smaller pressure reductions (±6%). No projected pressure reductions are presented for cod or flatfish, and thus the impact of alternative scenarios is not available either.

Impact of using literature data on effectiveness of measures

In addition to survey data from experts, literature data on the effectiveness of measures has been compiled. The literature data points have been used in a similar way as the expert survey responses, and when it has been available, it has been used to replace the expert estimates of the effectiveness of the measure type. However, literature estimates are not available for all measure types. Thus, it is not possible to implement the model estimation and provide the results relying entirely on the literature data on effectiveness of measure types. Thus, the model including the literature estimates is a combination of literature and expert data on effectiveness of measure types. The origin of other data components is not affected.

For commercial fish, only 6 estimates from 4 studies could be included in the SOM model. The projected pressure reductions from existing measures are not affected by the inclusion of literature data, as the data are few and none of the measure types with literature data are implemented in the SOM analysis. Thus, the results on total pressure reductions or sufficiency of measures to achieve GES or specific state improvements do not change.

Evaluation of quality and confidence

The SOM analysis for commercial fish has been able to assess the sufficiency of existing measures to achieve GES/state improvements for herring and sprat. Results for cod and plaice have been left out due to too few data points, including projected pressure reductions, total pressure reductions and sufficiency of measures for achieving state improvements. This stems from having too few estimates on the effectiveness of measure types.

The overall certainty of the assessment for commercial fish could be characterized as low to moderate. Experts from six coastal countries contributed to the assessment. The total number of experts contributing to the surveys is high for both the effectiveness of measures and pressure-state part, but some individual elements suffer from a low amount of data. The results on pressure reductions and the sufficiency of measures to achieve GES for cod and plaice have been excluded due to lack of data on the effectiveness of measure types. Further, the results on the effectiveness of measure types are uncertain. As the effects of some important pressures to the state of commercial fish have not been estimated within the analysis (e.g. eutrophication), the pressure reductions and probability to achieve GES/state improvements are likely underestimated.

Quality and precision could potentially be improved with the collection of additional expert responses, particularly on the effectiveness of measure types for cod and plaice, but changes to the assessment structure are required before a new assessment is made (see section Lessons learned).

For the individual results, certainty ranges from low to high for the effectiveness of measures types, is high for the projected reductions in pressures, and from low to high for required pressure reductions. These uncertainties should be kept in mind, in particular when examining the numeric estimates. The most common confidence level experts reported for their own evaluations is high for the effectiveness of measures and significance of pressures to state components. For the estimates of required pressure reductions, it is low or high for herring depending on the area, high for cod, moderate-high for sprat, and high for plaice. Additionally, there is a general lack of knowledge of pressures other than fishing on fish stocks. Hence, conclusions on the relationship between different pressures are uncertain.

There were some technical challenges that affected the survey implementation. Firstly, there was a problem in the survey software for the effectiveness of measure types survey that resulted in losing some responses. The original responses became often unusable, as it was not possible to identify which items had been skipped on purpose and which were lost data. This issue was addressed by sending follow-up invitations for experts to review and, when needed, complement their original saved response. Not all experts participated in the review and those responses had to be deleted from the final sample, thus the final numbers presented above represent only those with completed and reviewed responses. Secondly, the simultaneous assessment of effectiveness of a measure type and certainty of that effectiveness proved in some cases difficult, as it required placing non-quantitative dots in a coordinate system to generate quantitative estimates. The dots were translated into effectiveness and certainty values between 0 and 100. Some experts would have preferred that the quantitative estimates would have been visible and could have been transparently influenced.

When interpreting the results, the assumptions and generalizations that were made when collecting the input data and defining and using the data on measure type effectiveness and pressure-state linkages need to be taken into account. The input data are based mainly on expert elicitations rather than existing models and data, and reflect substantial uncertainty. For more information on the SOM methodology, data collection and assumptions, see this document.

Reflection on measure types

Much credit should go to the participants of the HELCOM Workshop on the analyses of Sufficiency of Measures (SOM) for Fish (SOM-FISH WS 1-2019) for their contributions to the formation of the measure types for fish. The fishing measures types generally and commercial fishing measure types specifically are a model for intra-topic consistency and overall clarity. However, deeper issues with the SOM approach's ability to consider topics dominated by dynamic management regimes may require a different approach to measure type design. This issue is discussed further in the section Lessons learned.

Lessons learned

The SOM approach relies on existing measures having a defined outcome or magnitude (e.g. requiring use of a technology, mandating standards or behaviour) that can be assumed to have a somewhat stable effect on the environment in the medium- to long-term. For measures that lack this quasi-predictable characteristic, through e.g. dynamic management or politically (rather than technically) driven decision making, the application of the assumption of stable effect may not be correct. In the case of commercial fisheries, the rate of both scientific advice and management decisions of the Common Fisheries Policy (CFP) would appear to violate the assumption of stable effect. While the typical year to year change may be minimal and within the ability of the SOM approach to consider, the ability of the CFP to react (or not react) to unknown future events greatly decreases the predictability of the measure type. One solution could be to have these dynamic measures directly affect pressures or state abundances in the analysis, rather than reducing human activities as they do now. This may better capture the variability of these measures by not requiring impacts flow through specific activity-pressure relationships. However, this would likely cause significant difficulties for assessing commercial fishing activities on other related topics, e.g. benthic habitats, and may prove to be very difficult for experts to assess. Due to the significant impact fishing has on many aspects of the Baltic Sea environment, this complex issue should be a development priority, not necessarily to ensure an assessment of the sufficiency of measures in maintaining commercial fish stocks but rather targeted at maintaining and improving multi-topic model integration.

A second and related point of concern is the use of the ICES SSB reference values as proxies for thresholds for good environmental status. Implicit in the idea of an environmental threshold is the idea of minimizing impact. As the SSB thresholds are rather related to the objective of maximum yield, this indicator is not designed to be met and then exceeded by some additional margin. In a situation like the SOM assessment, they may need to be expected to act more like targets which could accept some level of negative deviation (i.e.

the target is not met) rather than thresholds which would not accept that scenario. The use of dynamic management may reinforce this situation by providing greater opportunity to correct for negative deviations and thereby making them more acceptable in the short term. As a result, these threshold values may not be functioning in the same way as other threshold values in the SOM analysis.

Use of results, implications and future perspectives

The usefulness of the results of the analysis is limited due to low number of experts contributing to some aspects of the evaluation and methodological concerns specific to commercially managed fish in the SOM analysis. However, individual results remain relevant to environmental management in the Baltic Sea region, particularly effectiveness and impact of measures and significance of pressures. These result types avoid many of the methodological concerns discussed previously and, in some cases, are based on a quite high number of contributing experts.

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ICES (2019e). Herring (Clupea harengus) in subdivisions 25–29 and 32, excluding the Gulf of Riga (central Baltic Sea). ICES Advice on fishing opportunities, catch, and effort. Baltic Sea Ecoregion: 29 May 2019. https://doi.org/10.17895/ices.advice.4748

ICES (2019f). Herring (Clupea harengus) in Subdivision 28.1 (Gulf of Riga). ICES Advice on fishing opportunities, catch, and effort. Baltic Sea Ecoregion: 29 May 2018. https://doi.org/10.17895/ices.advice.4749

ICES (2019g). Herring (Clupea harengus) in subdivisions 30 and 31 (Gulf of Bothnia). ICES Advice on fishing opportunities, catch, and effort. Baltic Sea Ecoregion Version 2: 26 July 2019. https://doi.org/10.17895/ices.advice.4750

ICES (2019h). Plaice (Pleuronectes platessa) in subdivisions 21–23 (Kattegat, Belt Seas, and the Sound). ICES Advice on fishing opportunities, catch, and effort. Baltic Sea Ecoregion: 29 May 2019. https://doi.org/10.17895/ices.advice.4751

ICES (2019i). Plaice (Pleuronectes platessa) in subdivisions 24–32 (Baltic Sea, excluding the Sound and Belt Seas). ICES Advice on fishing opportunities, catch, and effort. Baltic Sea Ecoregion Version 2: 26 July 2019. https://doi.org/10.17895/ices.advice.4752

ICES (2019j). Sprat (Sprattus sprattus) in subdivisions 22–32 (Baltic Sea). ICES Advice on fishing opportunities, catch, and effort. Baltic Sea Ecoregion: 29 May 2019. https://doi.org/10.17895/ices.advice.4754

Annexes

Annexes 1–9 contain the expert surveys as well as information on the measure types and the literature review. They are available on the SOM Platform workspace.

Annexes 10–12 contain graphs and tables that provide additional information and perspectives on the results.

Annex 1 Activity-pressure survey

All topic specific pressures are single activity pressures, so no activity-pressure survey is available.

Annex 2 Modified activity list (if modified)

The topic uses the standard activity list, so no modified activity list is available.

Annex 3 Measure types list

PDF containing the measure types used in the assessment of the effectiveness of measures for *Commercial fish*. Document includes examples of existing measures that if implemented would be included in the corresponding measure type.

Annex 4 Linking existing measures to measure types

Excel containing the identified existing measures and their relationship to the measure types used in the SOM analysis.

Annex 5 Literature review search terms

Excel containing the search terms used during the literature review on effectiveness of measures for *Commercial fish*.

Annex 6 Literature review summary

Excel document containing the effectiveness of measures data retrieved from the literature review.

Annex 7 Topic structure

Excel containing the relationships between measure types, activities, pressures, state components, and sub-basins. Also contains information on GES thresholds.

Annex 8 Effectiveness of measures survey

PDF of the Effectiveness of measures survey for *Commercial fish*.

Annex 9 Pressure-state survey

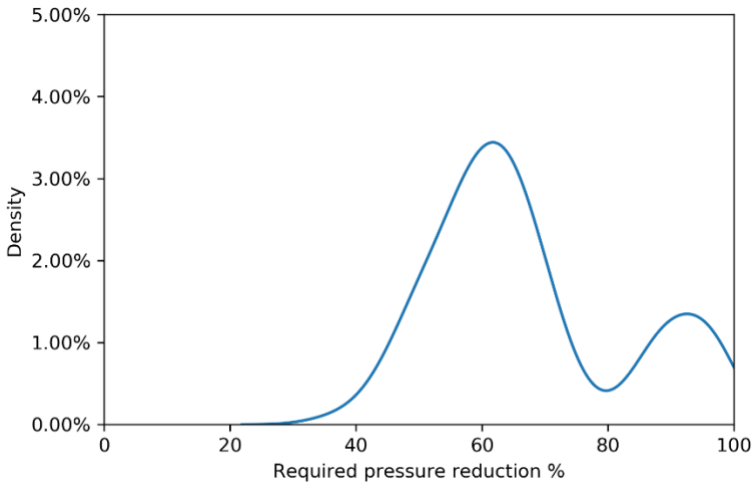
PDF of the Pressure-state survey for *Commercial fish*.

Annex 10 Supplementary results for required pressure reductions

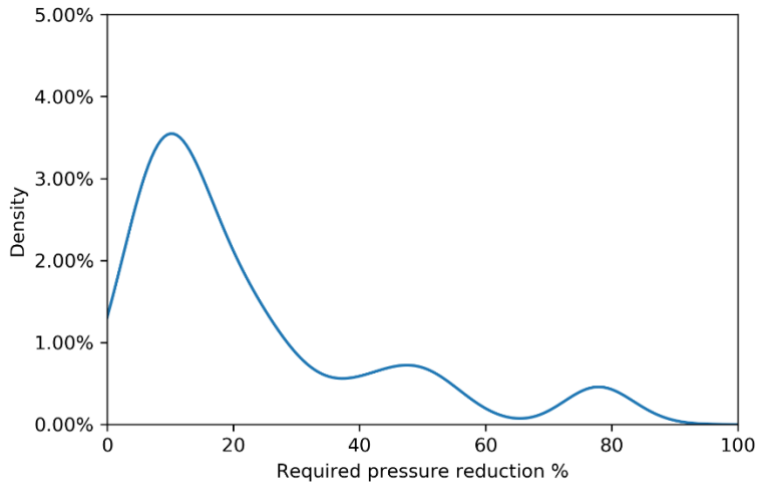
This annex presents the probability density functions of required pressure reductions to achieve a noticeable state improvement based on responses to the expert survey. The graphs show the probability distribution of the pooled expert responses on how much pressures should be reduced to achieve a noticeable state improvement. Pressure reduction is presented on the x-axis (0-100%) and probability density on the y-axis. The probability density function presents the probability of the pressure reduction falling within a particular range of values. This probability is given by the integral of the probability density over that range—that is, it is given by the area under the density function but above the horizontal axis and between the lowest and greatest values of the range.

Herring

SD 20-24, spring spawners
(No of experts = 9, Confidence = high)



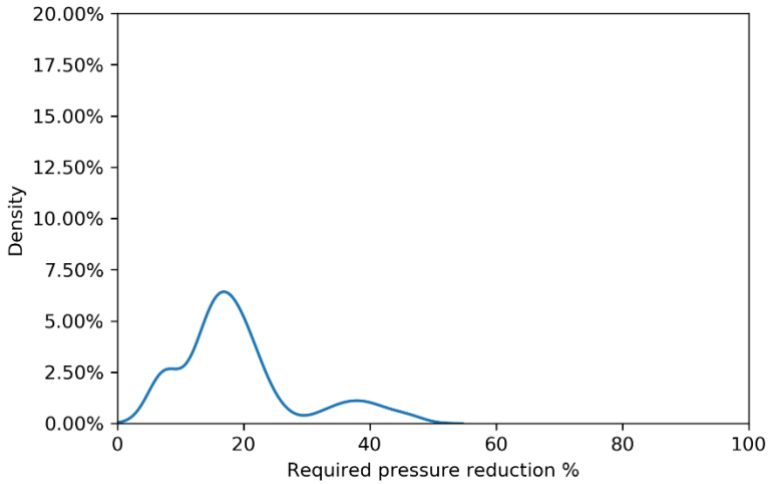
SD 25-29, 32 (excl. Gulf of Riga)
(No of experts = 13, Confidence = high)



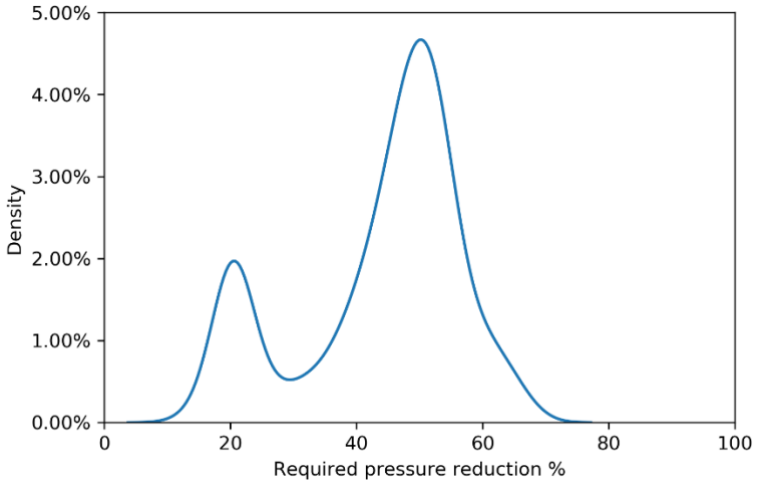
SD 28.1 (Gulf of Riga)

Insufficient data

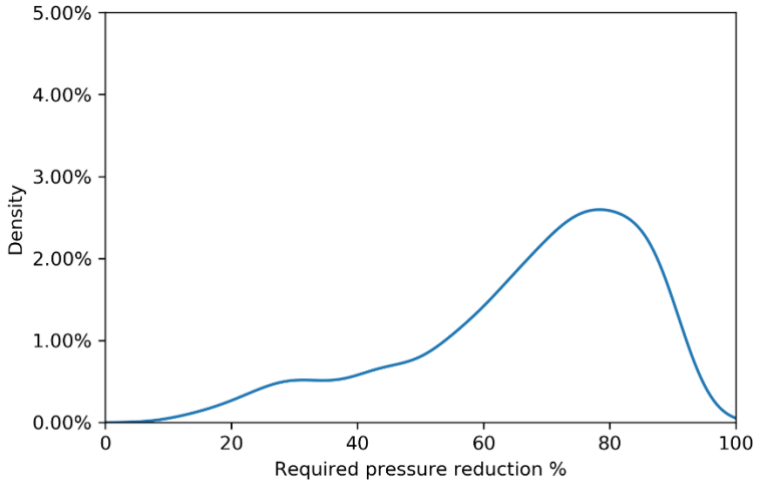
SD 30-31, 10% state improvement
(No of experts = 8, Confidence = low)

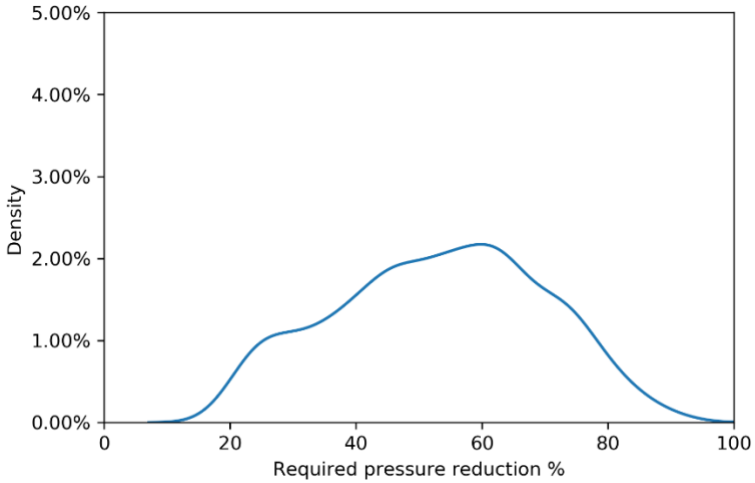
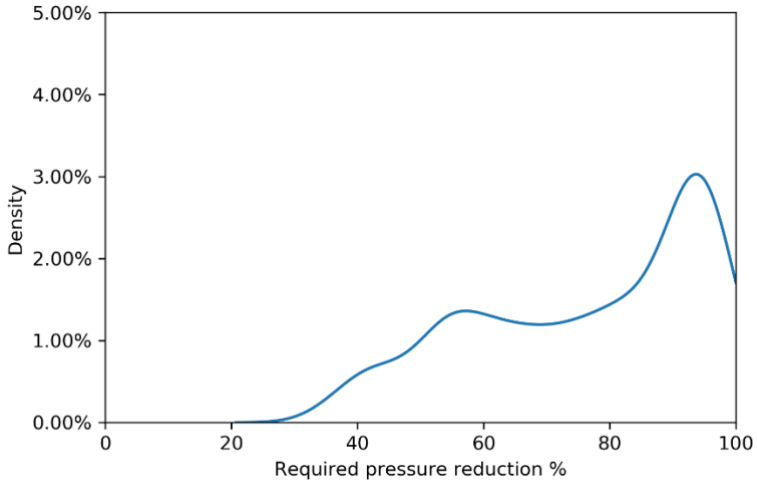


SD 30-31, 25% state improvement
(No of experts = 7, Confidence = low)



SD 30-31, 50% state improvement
(No of experts = 8, Confidence = low)

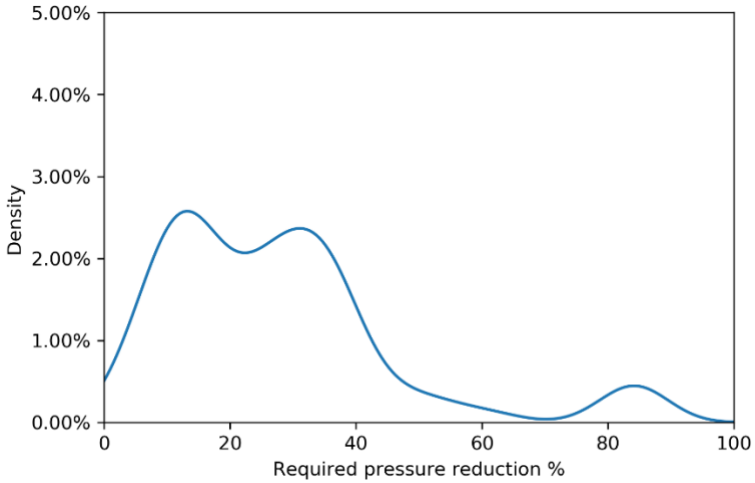


Cod	
Western Baltic (No of experts = 10, Confidence = high) 	**Eastern Baltic** (No of experts = 18, Confidence = high) 

Sprat

SD 22-30, 32

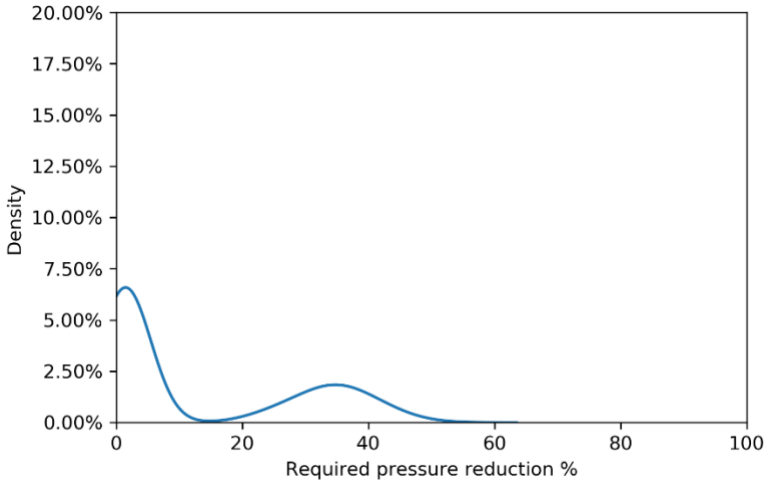
(No of experts = 16, Confidence = high-moderate)



Plaice

SD 22-30, 32

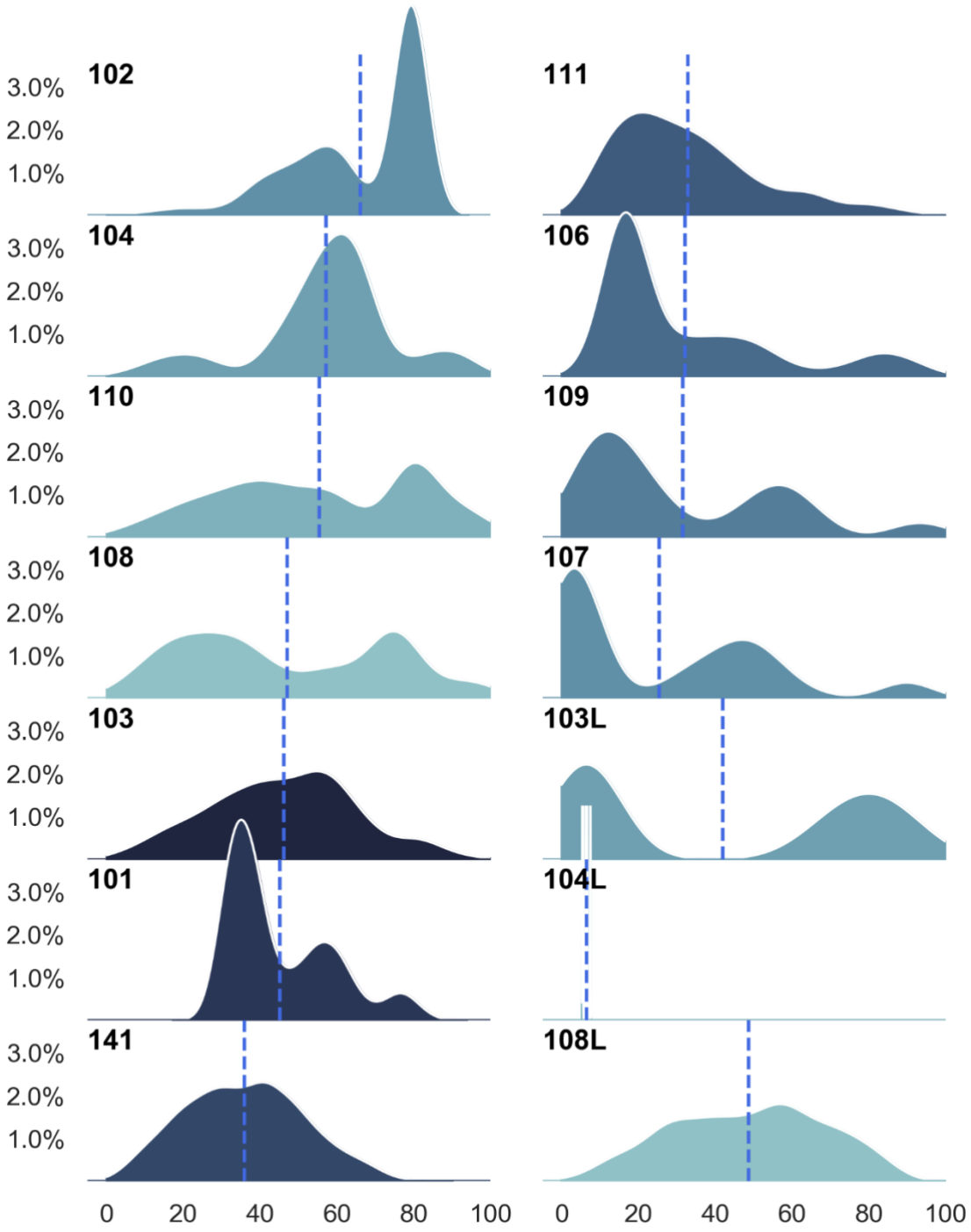
(No of experts = 6, Confidence = high)



Annex 11 Supplementary results for effectiveness of measures

Table A1. Distribution of the effectiveness of measure types in controlling the pressure *of targeted extraction and bycatch of cod.* The effectiveness of a measure type is the percent reduction in a pressure resulting from a specific activity. The graphs present the probability distribution of effectiveness, based on expert responses or literature estimates. The dashed line represents the expected value. Figures showing only a dashed line and no apparent probability distribution are point estimates without variation.

Pressure:	Targeted extraction and bycatch of cod
Activity:	Fish and shellfish harvesting (all gears; professional, recreational)
Measure type:	102: Spatial closures
	104: Technical measures to reduce catches of unwanted sizes of fish
	110: Ensure compliance with existing regulations (commercial and/or recreational)
	108: Catches of commercial fish in line with targets for MSY
	103: Technical measures to reduce catches of unwanted species
	101: Seasonal closures
	141: Unspecified MPA fisheries restrictions
	111: Promotion of sustainable fisheries (commercial and/or recreational)
	106: Measures to reduce recreational fishing (e.g. licenses)
	109: Bag limits (e.g. daily/seasonal) in recreational fisheries
	107: Measures to reduce commercial fishing capacity
	103L: Technical measures to reduce catches of unwanted species (literature based)
	104L: Technical measures to reduce catches of unwanted sizes of fish (literature based)
	108L: Catches of commercial fish in line with targets for MSY (literature based)
Expert assessment:	5-6 experts, confidence = high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80
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Table A2. Distribution of the effectiveness of measure types in controlling the pressure *of targeted extraction and bycatch of flatfish.* The effectiveness of a measure type is the percent reduction in a pressure resulting from a specific activity. The graphs present the probability distribution of effectiveness, based on expert responses or literature estimates. The dashed line represents the expected value. Figures showing only a dashed line and no apparent probability distribution are point estimates without variation.

Pressure:	Targeted extraction and bycatch of flatfish
Activity:	Fish and shellfish harvesting (all gears; professional, recreational)
Measure type:	102: Spatial closures
	103: Technical measures to reduce catches of unwanted species
	107: Measures to reduce commercial fishing capacity
	101: Seasonal closures
	110: Ensure compliance with existing regulations (commercial and/or recreational)
	108: Catches of commercial fish in line with targets for MSY
	104: Technical measures to reduce catches of unwanted sizes of fish
	112: CFP multi-annual plan
	141: Unspecified MPA fisheries restrictions
	111: Promotion of sustainable fisheries (commercial and/or recreational)
	106: Measures to reduce recreational fishing (e.g. licenses)
	109: Bag limits (e.g. daily/seasonal) in recreational fisheries
Expert assessment:	5-6 experts, confidence = high

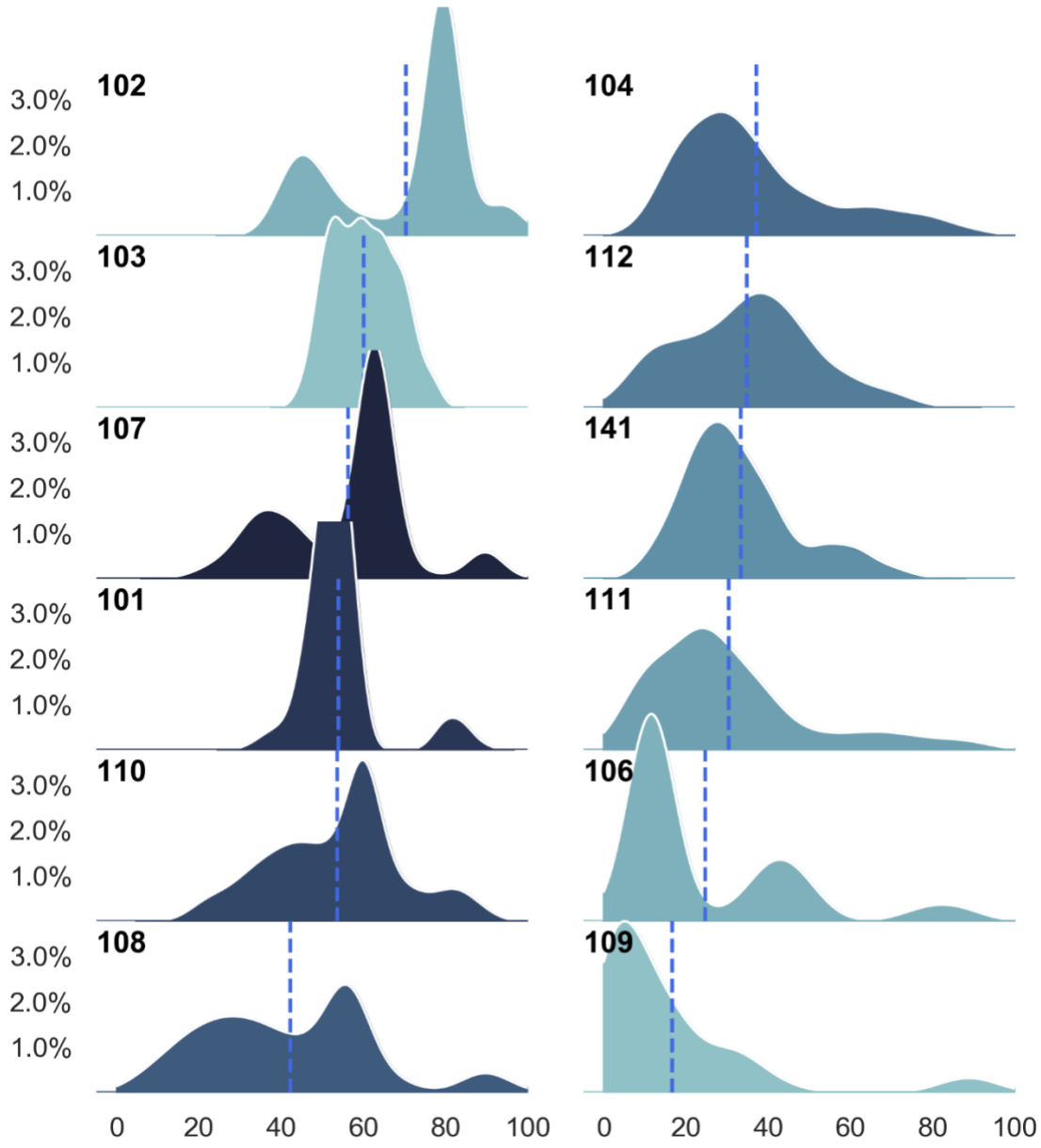
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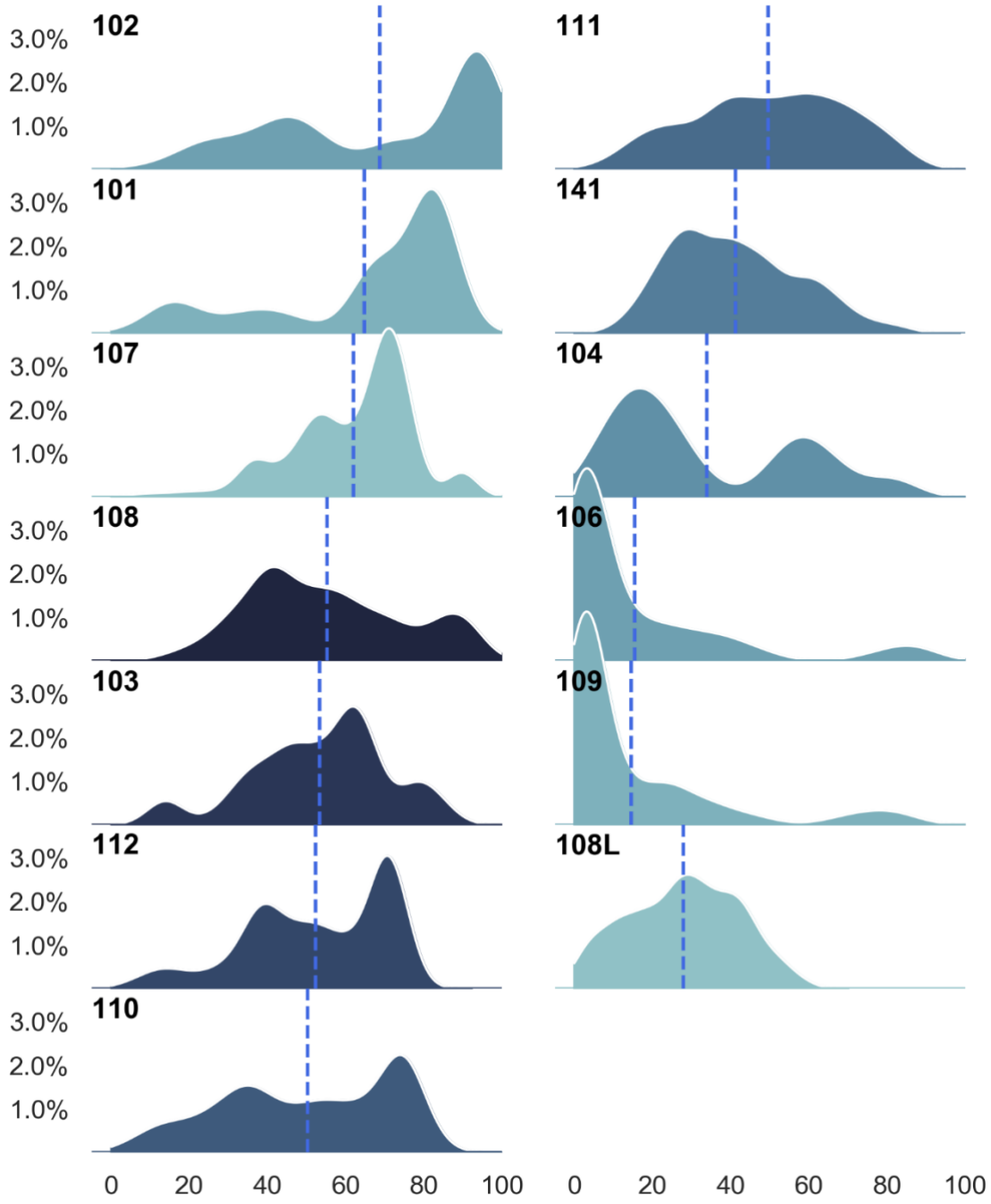
Table A3. Distribution of the effectiveness of measure types in controlling the pressure *of targeted extraction and bycatch of pelagic fish.* The effectiveness of a measure type is the percent reduction in a pressure resulting from a specific activity. The graphs present the probability distribution of effectiveness, based on expert responses or literature estimates. The dashed line represents the expected value. Figures showing only a dashed line and no apparent probability distribution are point estimates without variation.

Pressure:	Targeted extraction and bycatch of pelagic fish
Activity:	Fish and shellfish harvesting (all gears; professional, recreational)
Measure type:	102: Spatial closures
	101: Seasonal closures
	107: Measures to reduce commercial fishing capacity
	108: Catches of commercial fish in line with targets for MSY
	103: Technical measures to reduce catches of unwanted species
	112: CFP multi-annual plan
	110: Ensure compliance with existing regulations (commercial and/or recreational)
	111: Promotion of sustainable fisheries (commercial and/or recreational)
	141: Unspecified MPA fisheries restrictions
	104: Technical measures to reduce catches of unwanted sizes of fish
	106: Measures to reduce recreational fishing (e.g. licenses)
	109: Bag limits (e.g. daily/seasonal) in recreational fisheries
	108L: Catches of commercial fish in line with targets for MSY (literature based)
Expert assessment:	5-7 experts, confidence = high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Annex 12 Impacts of measure types

Table A4. Impacts of measure types (%) in reducing the targeted extraction and bycatch of commercial fish. The impact shows how much the measure type reduces the pressure across all activities contributing to the pressure.

Pressure on commercial fish at the Baltic Sea scale	Measure type	Mean (Standard deviation)
Targeted extraction and bycatch of cod	Spatial closures	64 (18)
	Technical measures to reduce catches of unwanted sizes of fish	56 (18)
	Ensure compliance with existing regulations (commercial and/or recreational)	55 (26)
	Catches of commercial fish in line with targets for MSY	49 (28)
	Technical measures to reduce catches of unwanted species	46 (19)
	Seasonal closures	insufficient data
	Unspecified MPA fisheries restrictions	insufficient data
	Measures to reduce recreational fishing (e.g. licenses)	34 (24)
	Bag limits (e.g. daily/seasonal) in recreational fisheries	insufficient data
	Promotion of sustainable fisheries (commercial and/or recreational)	31 (18)
	Measures to reduce commercial fishing capacity	25 (27)
Targeted extraction and bycatch of flatfish	Spatial closures	72 (15)
	Technical measures to reduce catches of unwanted species	60 (8)
	Measures to reduce commercial fishing capacity	57 (16)
	Ensure compliance with existing regulations (commercial and/or recreational)	55 (16)
	Seasonal closures	insufficient data
	Catches of commercial fish in line with targets for MSY	42 (21)
	Technical measures to reduce catches of unwanted sizes of fish	38 (19)
	CFP multi-annual plan	35 (17)
	Unspecified MPA fisheries restrictions	insufficient data
	Promotion of sustainable fisheries (commercial and/or recreational)	32 (19)
	Measures to reduce recreational fishing (e.g. licenses)	insufficient data
	Bag limits (e.g. daily/seasonal) in recreational fisheries	insufficient data
Targeted extraction and bycatch of pelagic fish	Spatial closures	68 (27)
	Seasonal closures	66 (23)
	Measures to reduce commercial fishing capacity	61 (16)
	Catches of commercial fish in line with targets for MSY	55 (19)
	Technical measures to reduce catches of unwanted species	54 (18)
	CFP multi-annual plan	54 (17)
	Ensure compliance with existing regulations (commercial and/or recreational)	52 (21)
	Promotion of sustainable fisheries (commercial and/or recreational)	50 (20)
	Unspecified MPA fisheries restrictions	42 (16)
	Technical measures to reduce catches of unwanted sizes of fish	34 (24)
	Measures to reduce recreational fishing (e.g. licenses)	16 (23)
	Bag limits (e.g. daily/seasonal) in recreational fisheries	14 (20)